VOL. 2 NO. 10

OCTOBER 1961

RADIO & ELECTRONIC COMPONENTS

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Technical articles will be gladly considered for publication, payment being made by arrangement. Articles should preferably be from 3,000 to 4,000 words, but no rigid limit is imposed. Manuscripts should be typewritten, in double spacing, on one side of the paper only. Diagrams may be drawn in pencil provided that they are clear and adequately lettered. For half-tone illustrations, glossy prints are preferable. While every care is taken of MSS. submitted, no responsibility can be accepted in case of loss.

CONTENTS

Commentary ... 729
The Stability of Permanent Magnets ... 731
By A. G. Clegg, M.Sc., Ph.D.
Non-Linear Resistors—A Review of Some Single Circuit Elements ... 739
By John Dalton, A.M.I.E.E., A.M.Brit.I.R.E.
Correspondence ... 743
Battery Research and Development ... 745
By Dr. M. Barak
Farnborough Air Show 1961—A General Survey ... 750
A Survey of Transformers in the Electronics Industry. Part 2 755
By D. R. Adams
Applications of Silicon *p-n* Junction Capacitors ... 760
By A. G. Scott
New Components Annual ... 762
Vacuum Forming of Plastics—Its Application to the Radio and Electronics Field ... 763
By R. W. Harwood, F.R.S.A.
Components for High-Fidelity Equipment. Part 1 ... 769
By John Borwick, B.Sc.
Electrical Engineers Exhibition 1962 ... 772
How the Lightning is Built ... 773
Electrochemical Polishing of Semiconductor Wafers ... 774
Microwave Amplification of Sound Waves ... 775
Solar Cell Installations ... 776
New Books ... 777
New Components ... 781
Manufacturers' Publications ... 785
Personalities ... 786
Activities in the Industry ... 788

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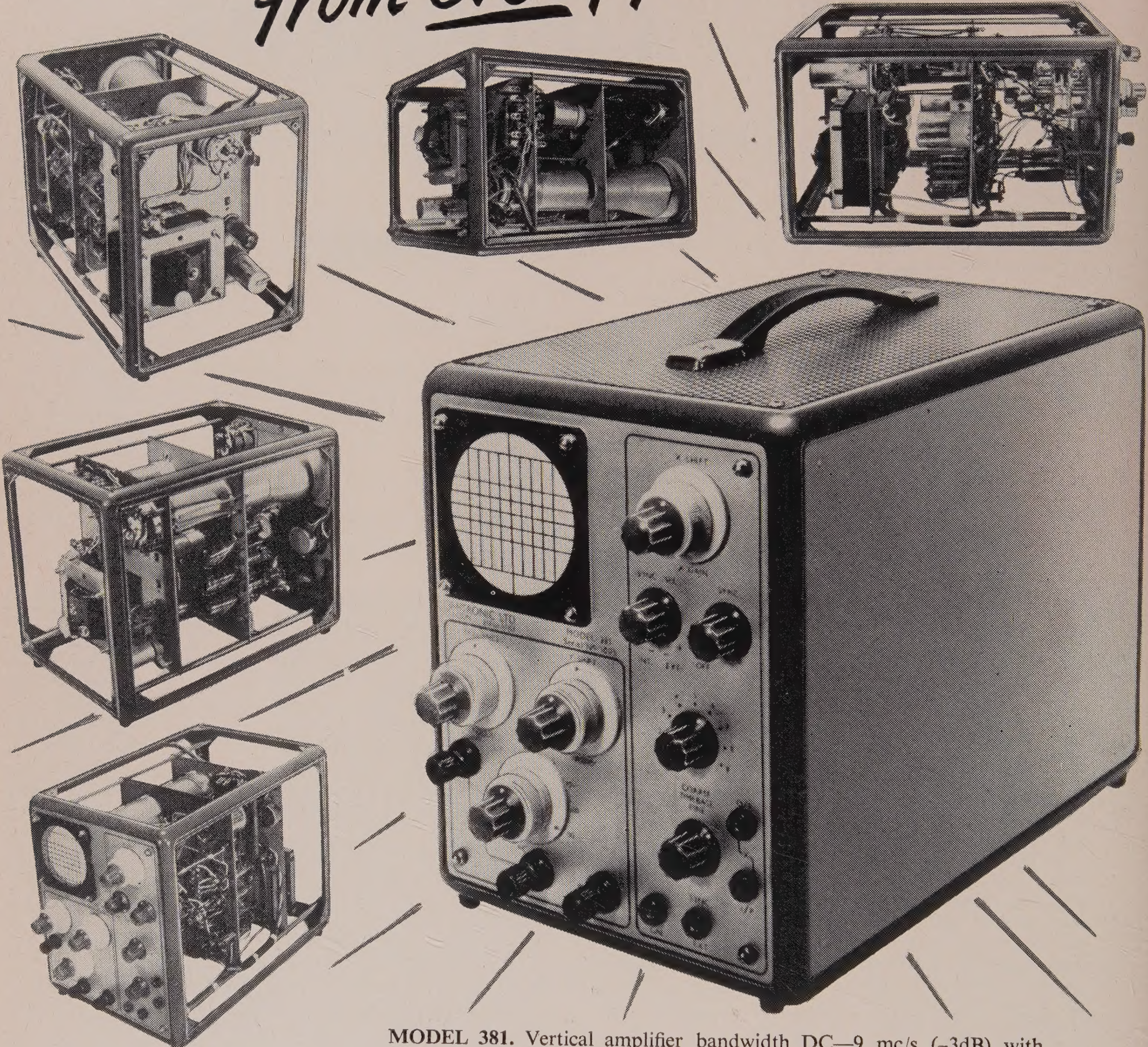

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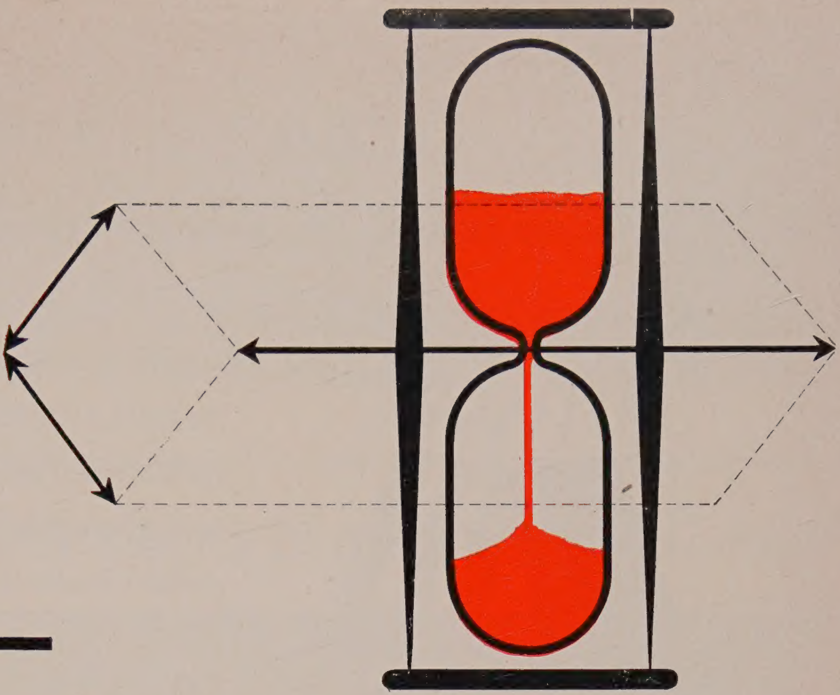

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RULES

(1) AWARDS. The constituent Associations are prepared to award up to 8 premiums of 30 guineas each to the writer or writers of eligible articles published between January and December in any one year. Some prizes will be awarded for purely technical articles as well as articles of commercial or interpretative merit.

(2) ELIGIBILITY. (a) Articles in any journal are eligible provided that the journal is available to the public generally, either by subscription or by open sale. (b) No articles can be accepted for consideration before publication in a journal eligible for the competition. In doubtful cases of eligibility the Panel of Judges shall decide. (c) The writers themselves must take the initiative and submit articles for consideration but this rule does not prevent acceptance of articles submitted by the editor of a journal. (d) Members of the Panel of Judges may select and submit articles for consideration by the Panel. (e) Candidates submitting articles must certify to the Secretary of the Awards Committee that they are not earning 25% or more of their income from fees for articles or from book royalties. When an article is by two or more authors each must be eligible under the above terms. In such a case the award of 30 guineas is shared between the writers. Any number of articles may be submitted by a single candidate.

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(4) PROCEDURE. Persons submitting articles for consideration of the Panel should send seven copies of the article together with a signed declaration that the writer (writers) is (are) eligible within Rule 2(e) to the Secretary of the Awards Committee, c/o The Electronic Engineering Association, 11 Green Street, Mayfair, London, W.1, formally submitting the article for consideration for an award. All entries must reach 11 Green Street not later than the 15th January 1962. Articles should be submitted for consideration as soon as possible after publication. Presentation of the awards is made soon after selection, which takes place in March. The names of the prizewinners are announced in the technical press and each prizewinner receives a personal letter informing him of his success.

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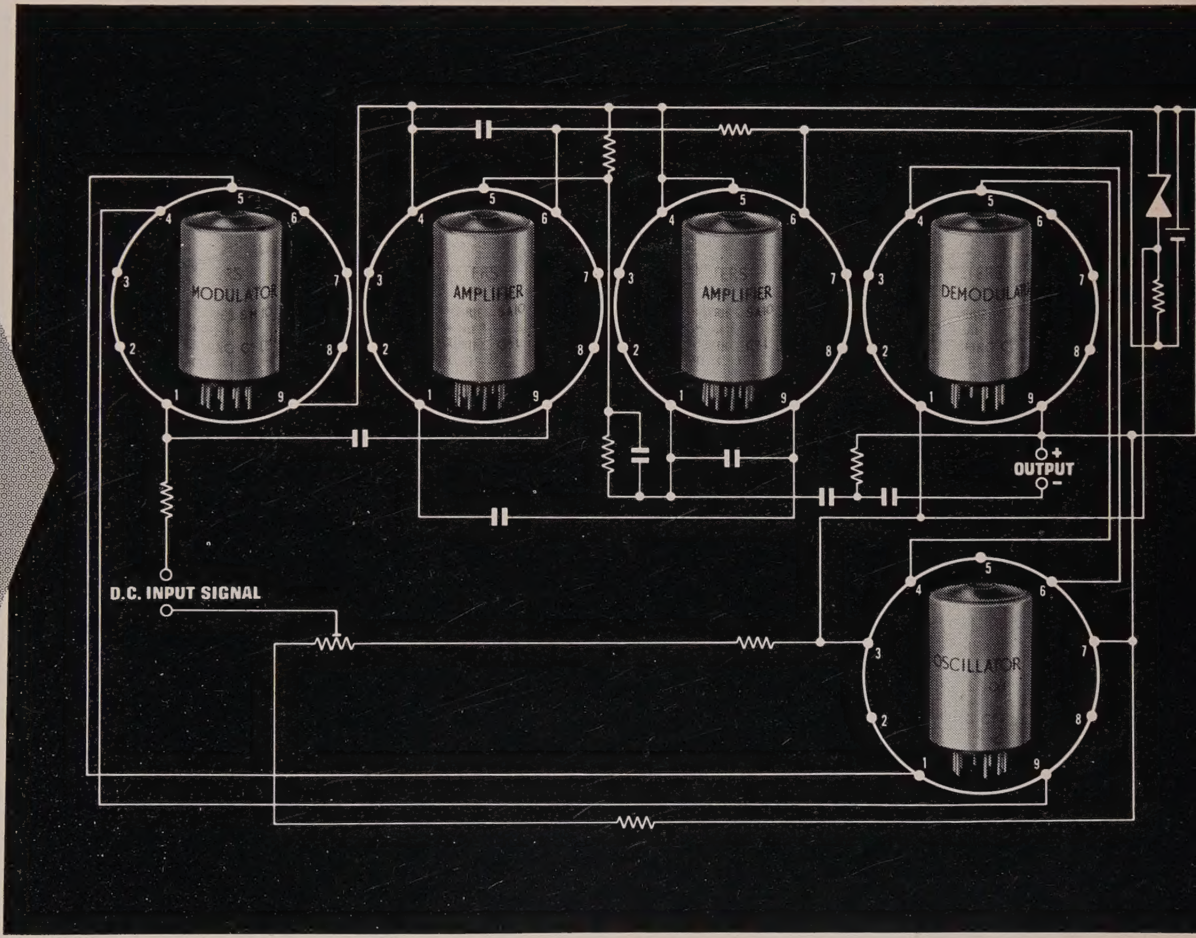

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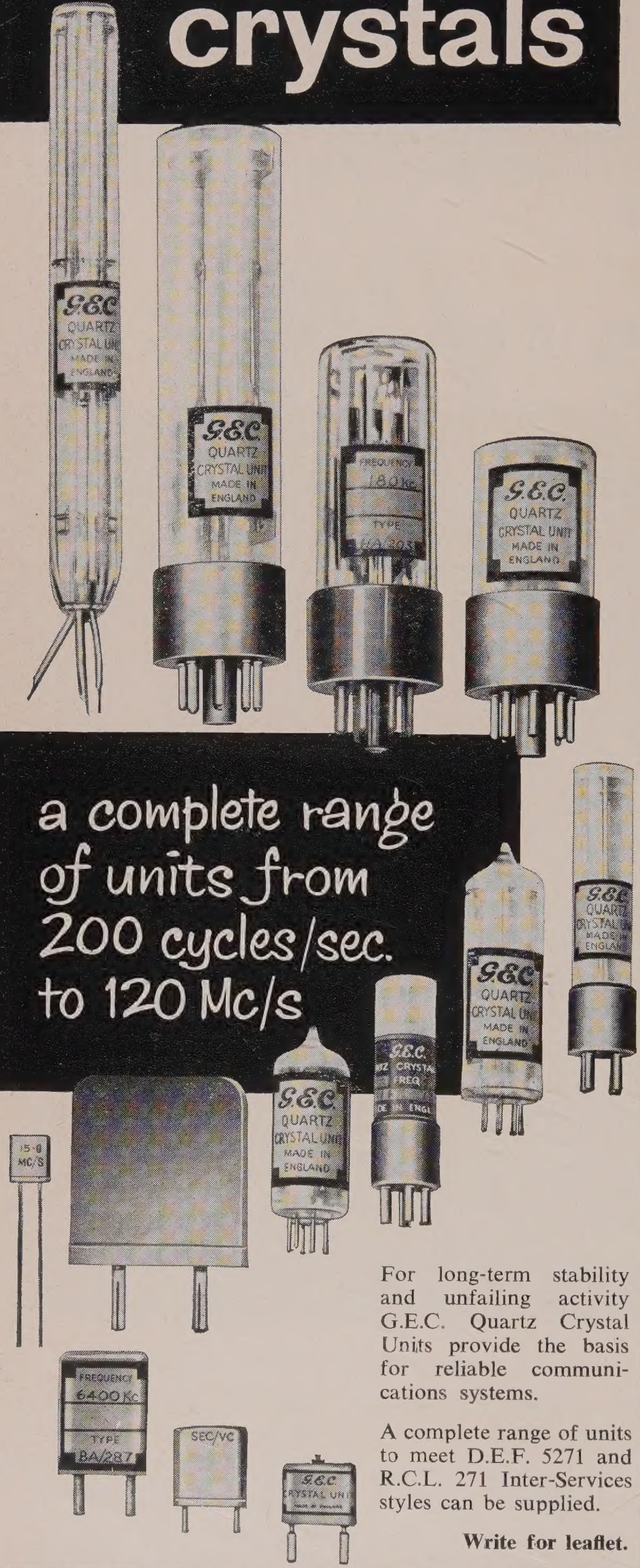

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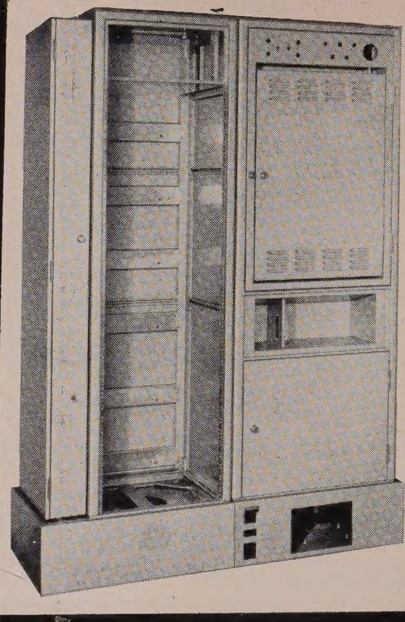

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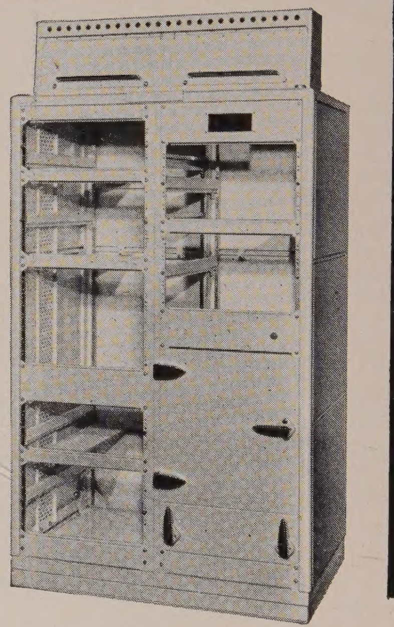

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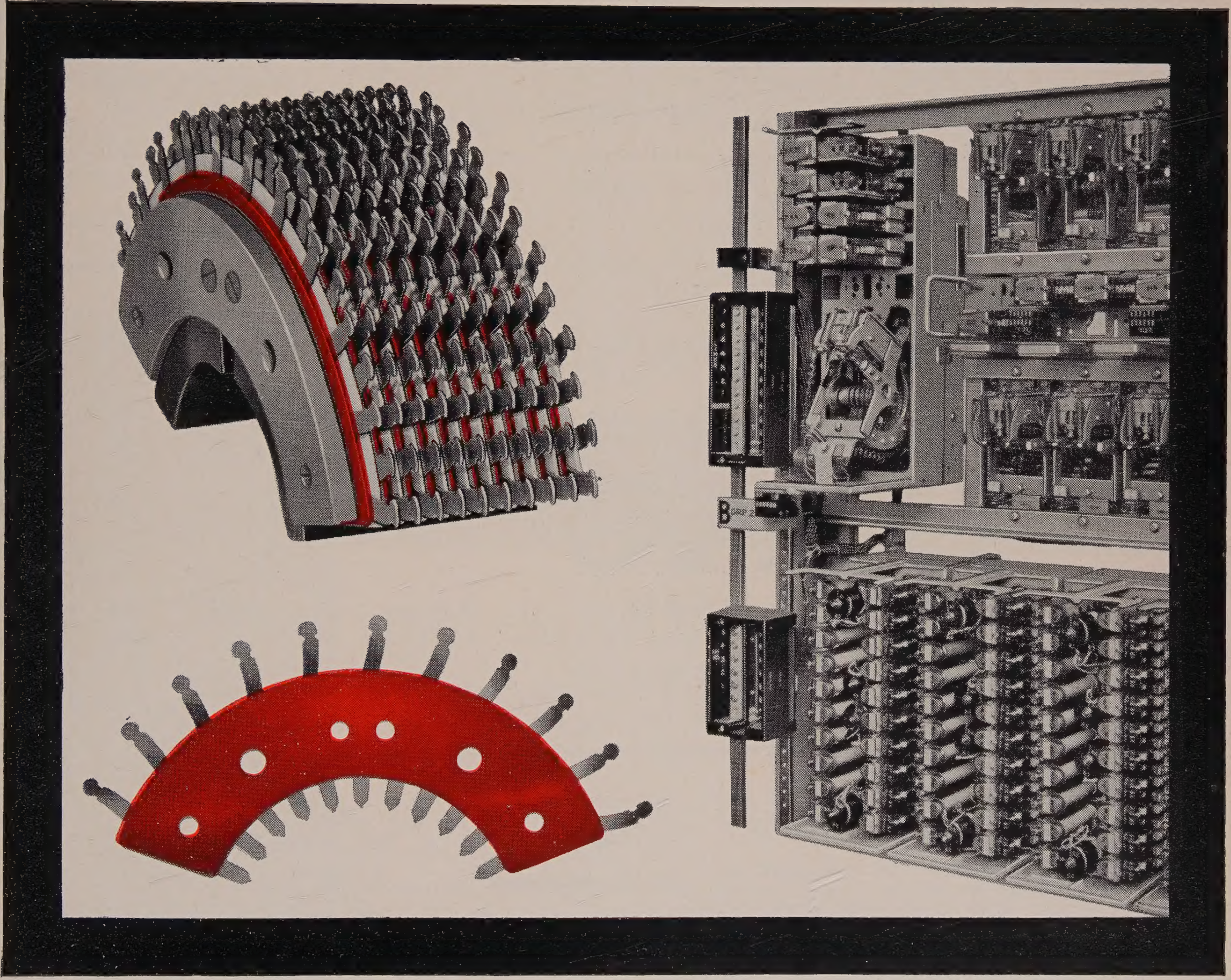

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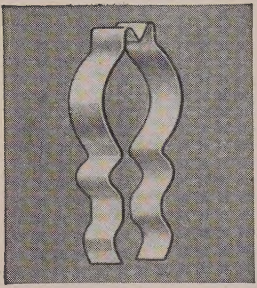

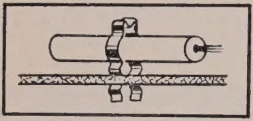

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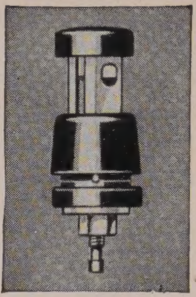

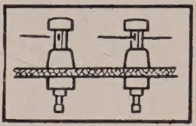

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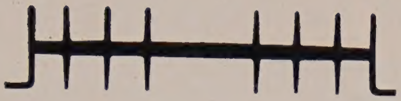

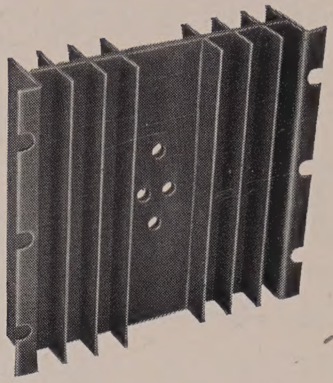

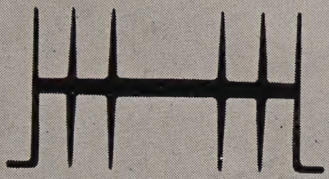

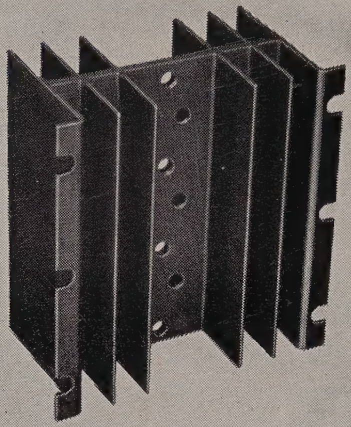

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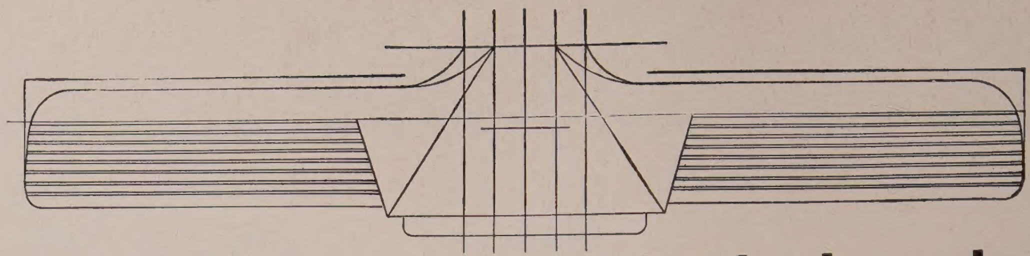

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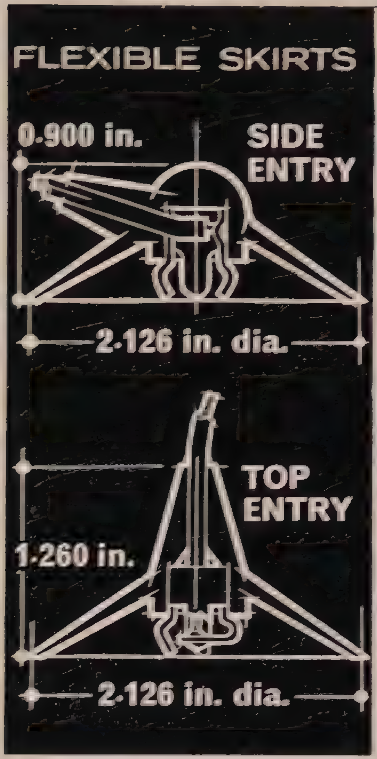

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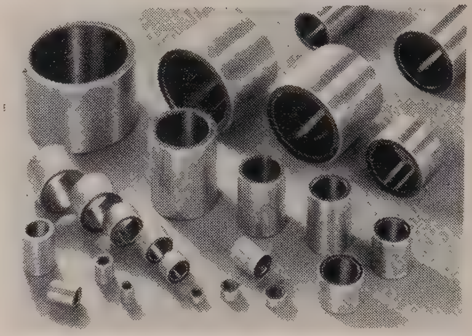

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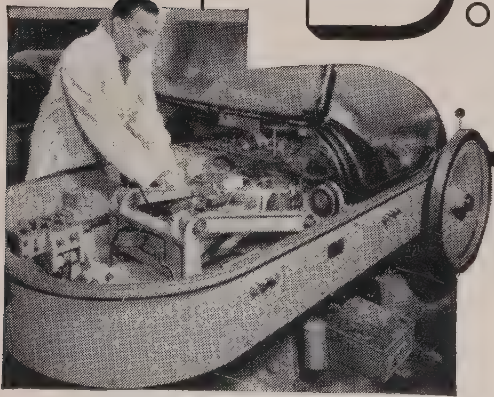

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TEMPERATURE LIMITS (State whether vacuum or atmospheric)

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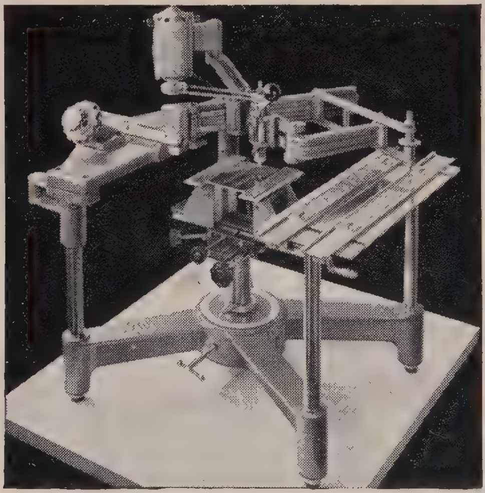

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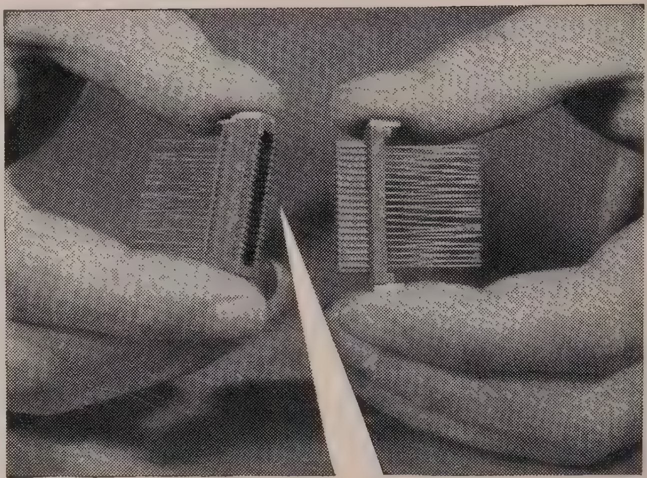

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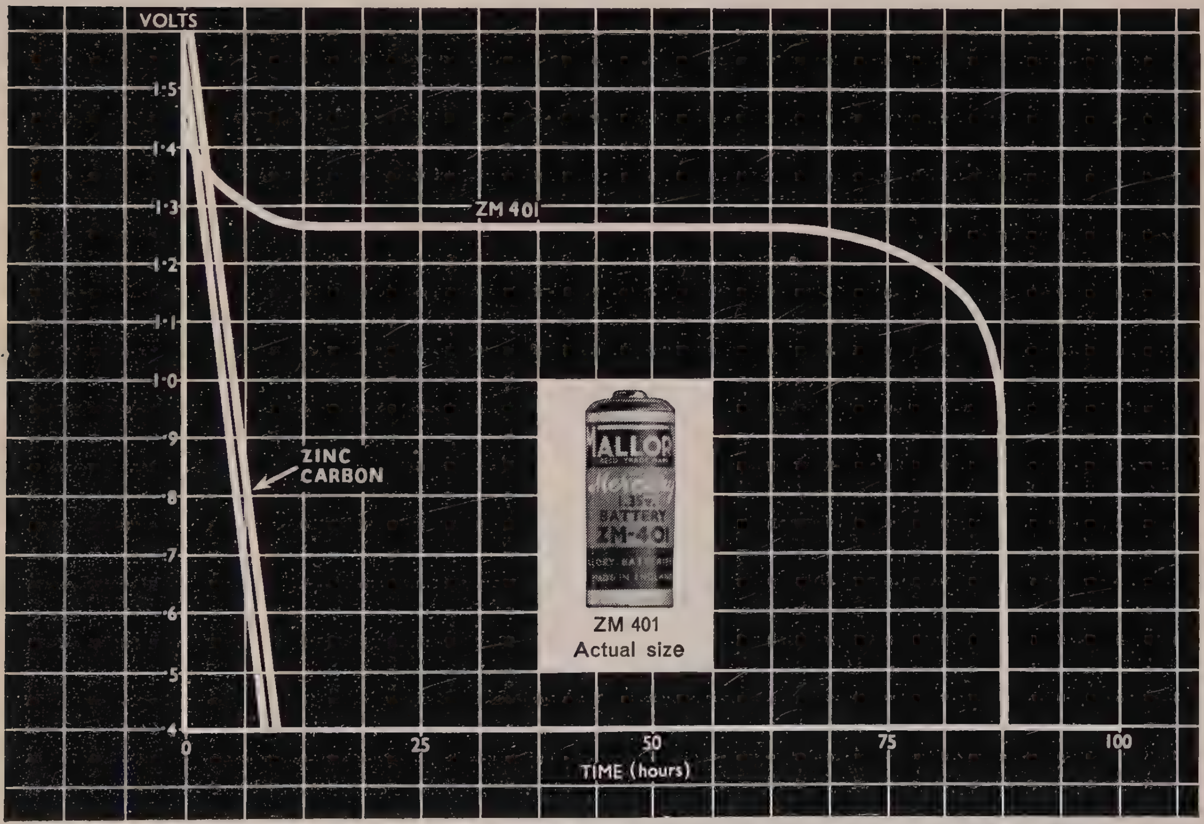

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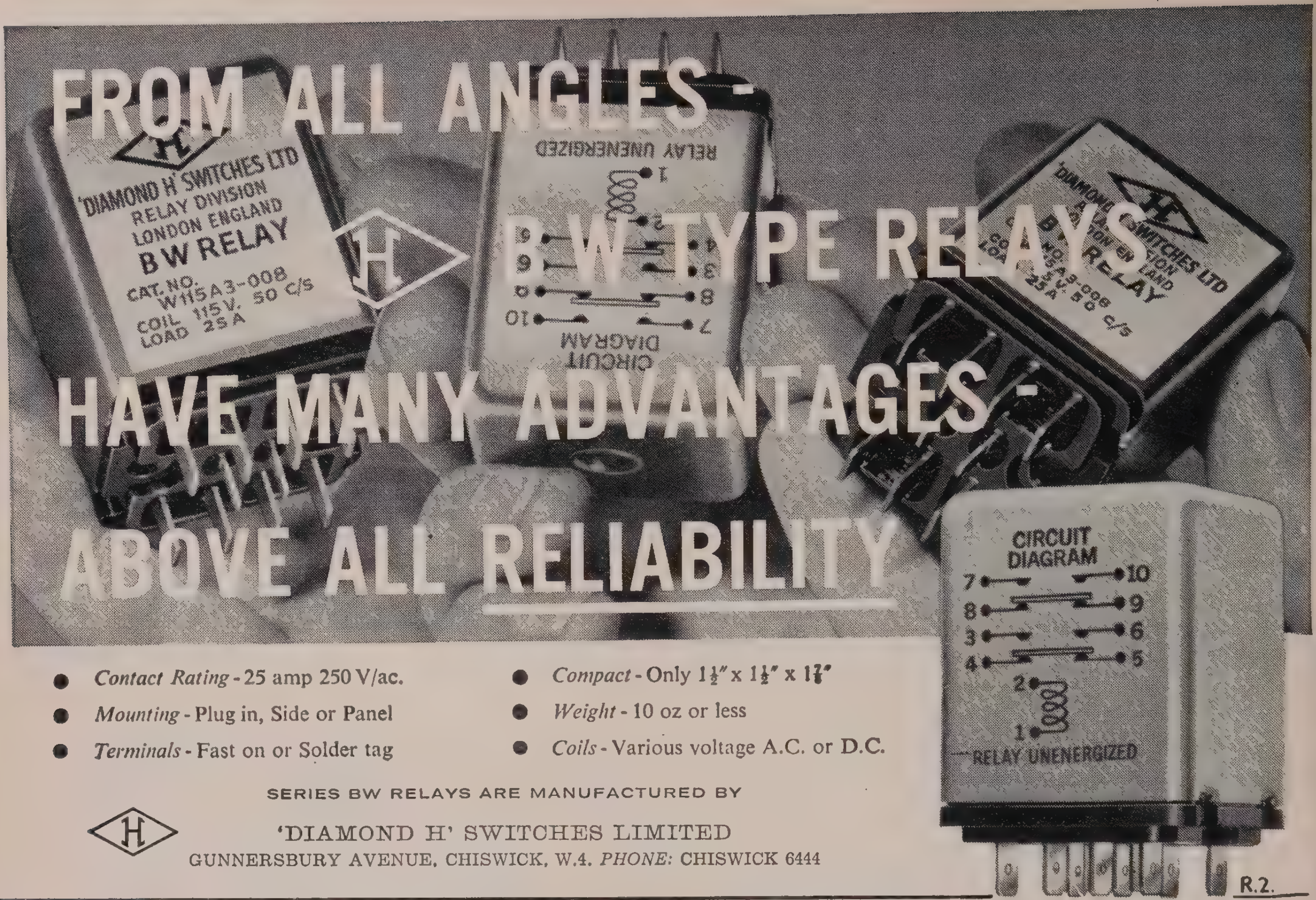

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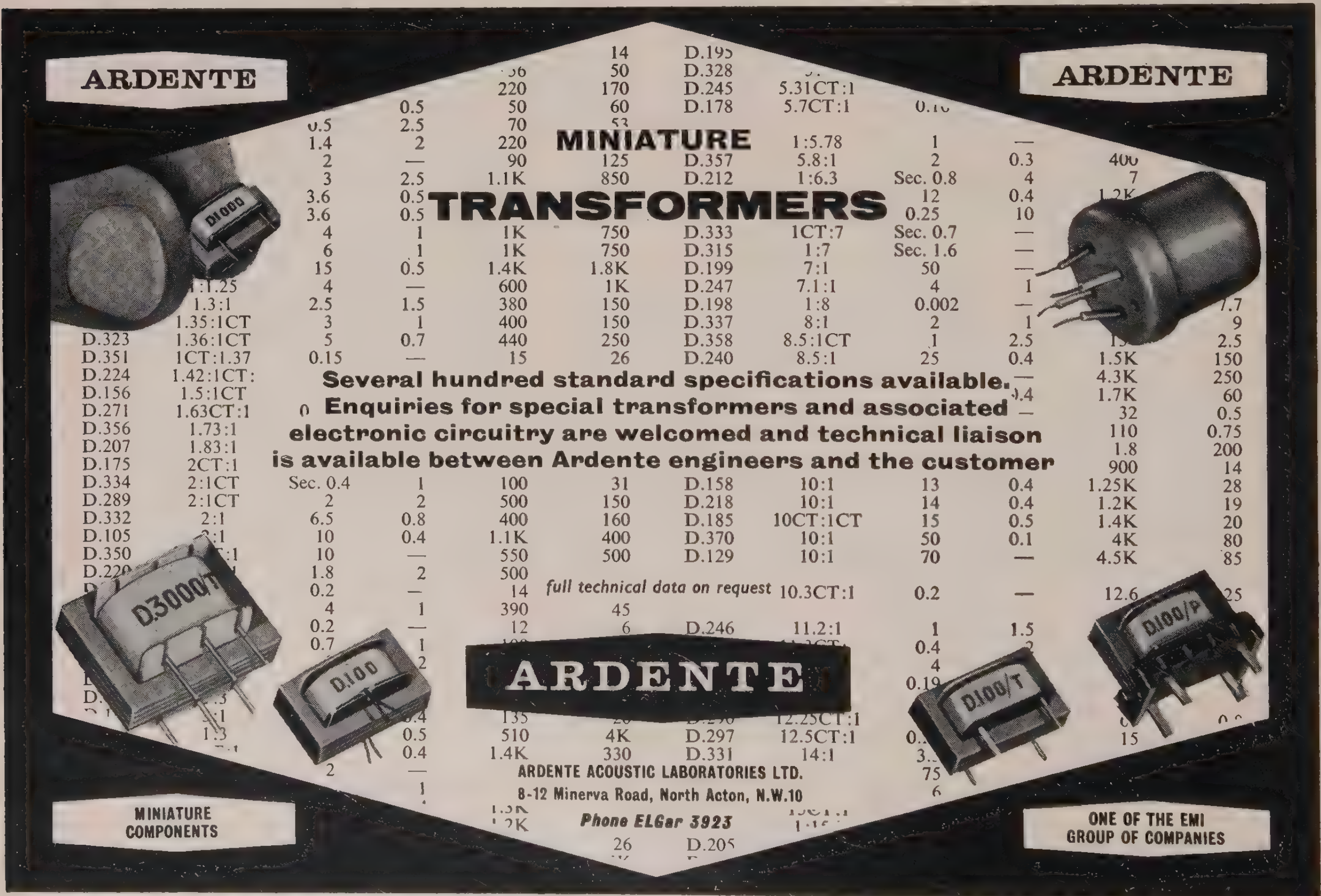

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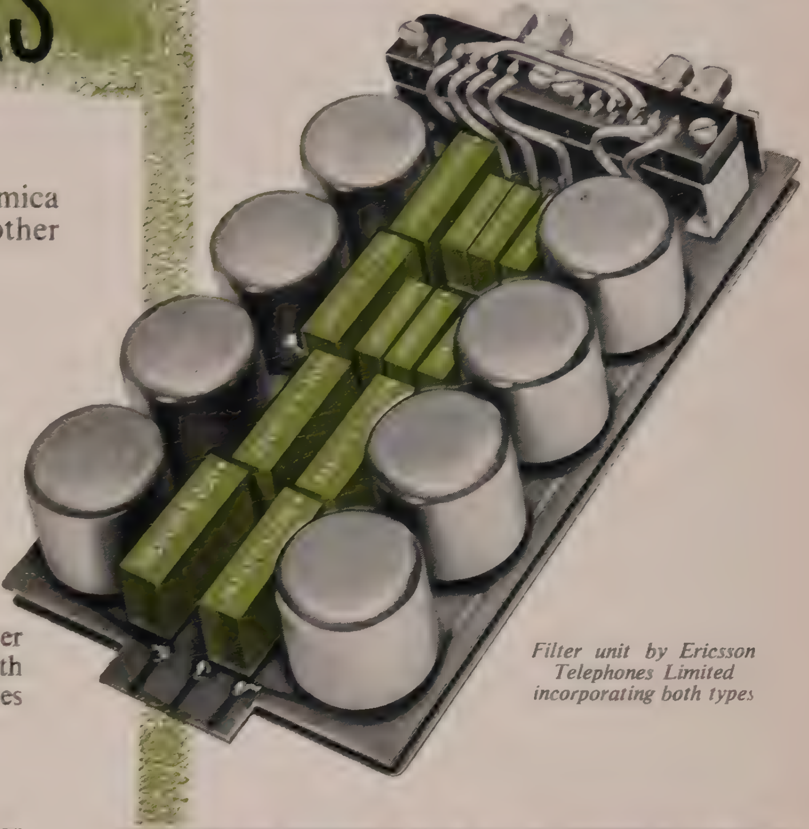

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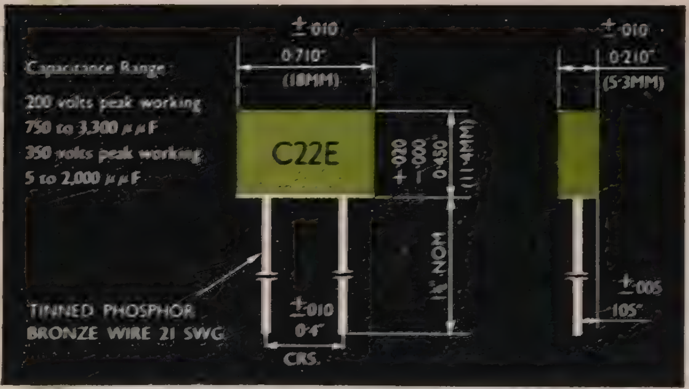

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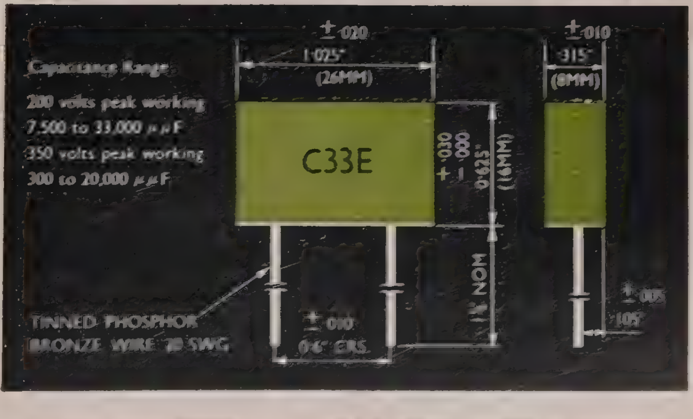

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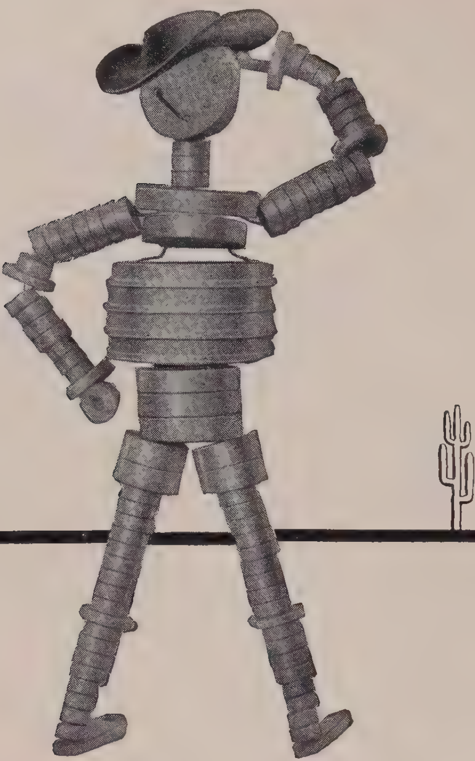

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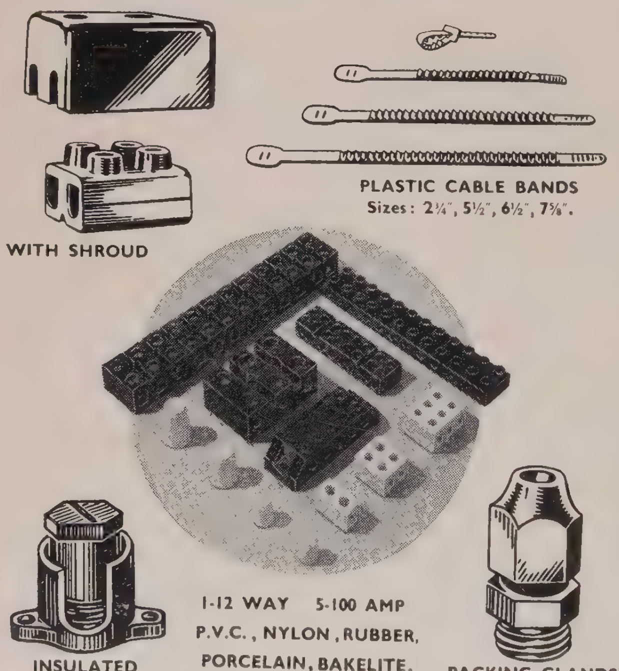

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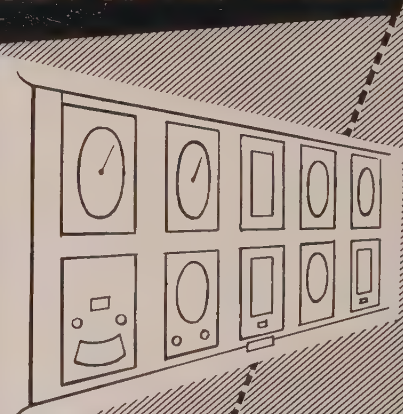

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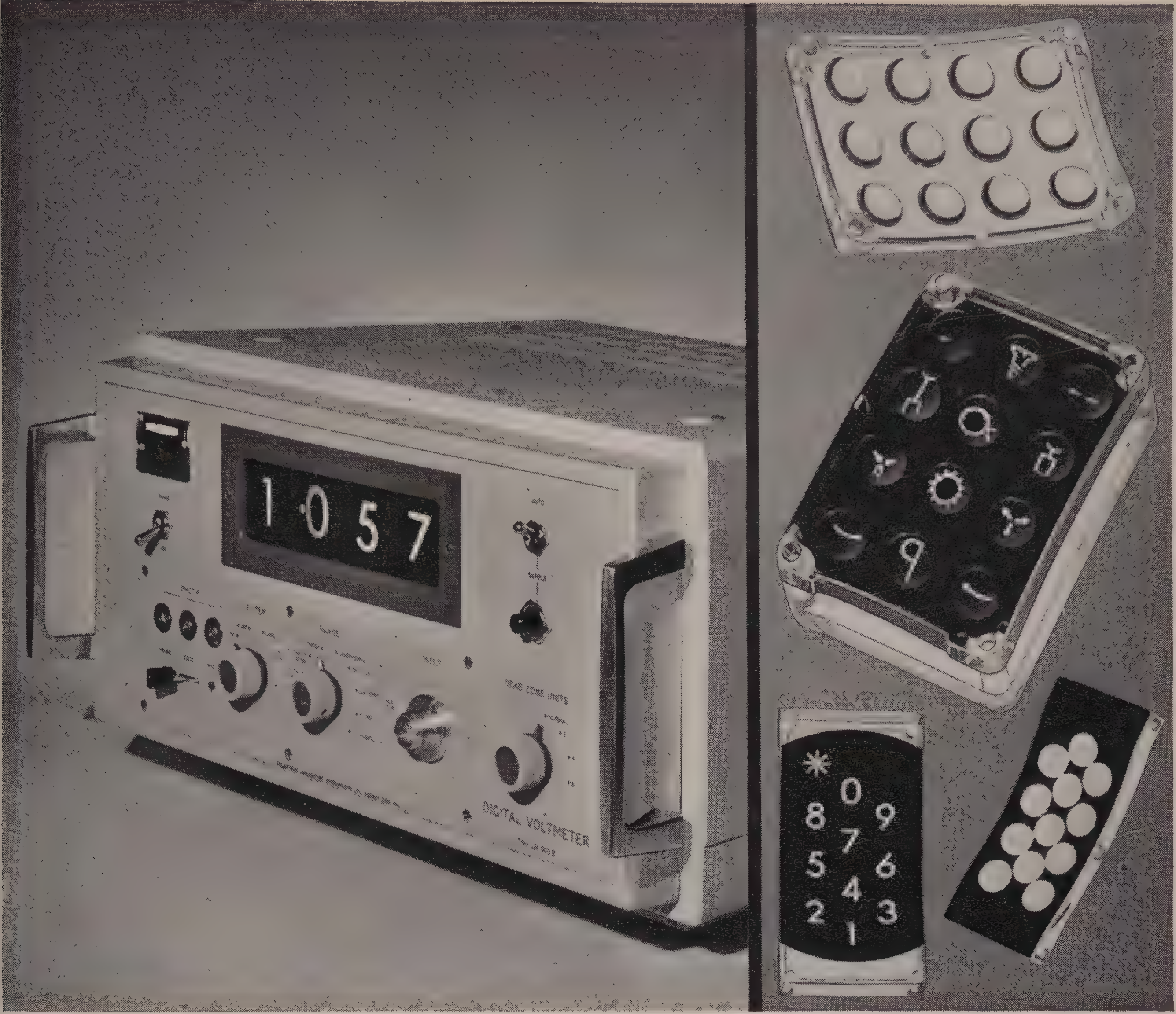

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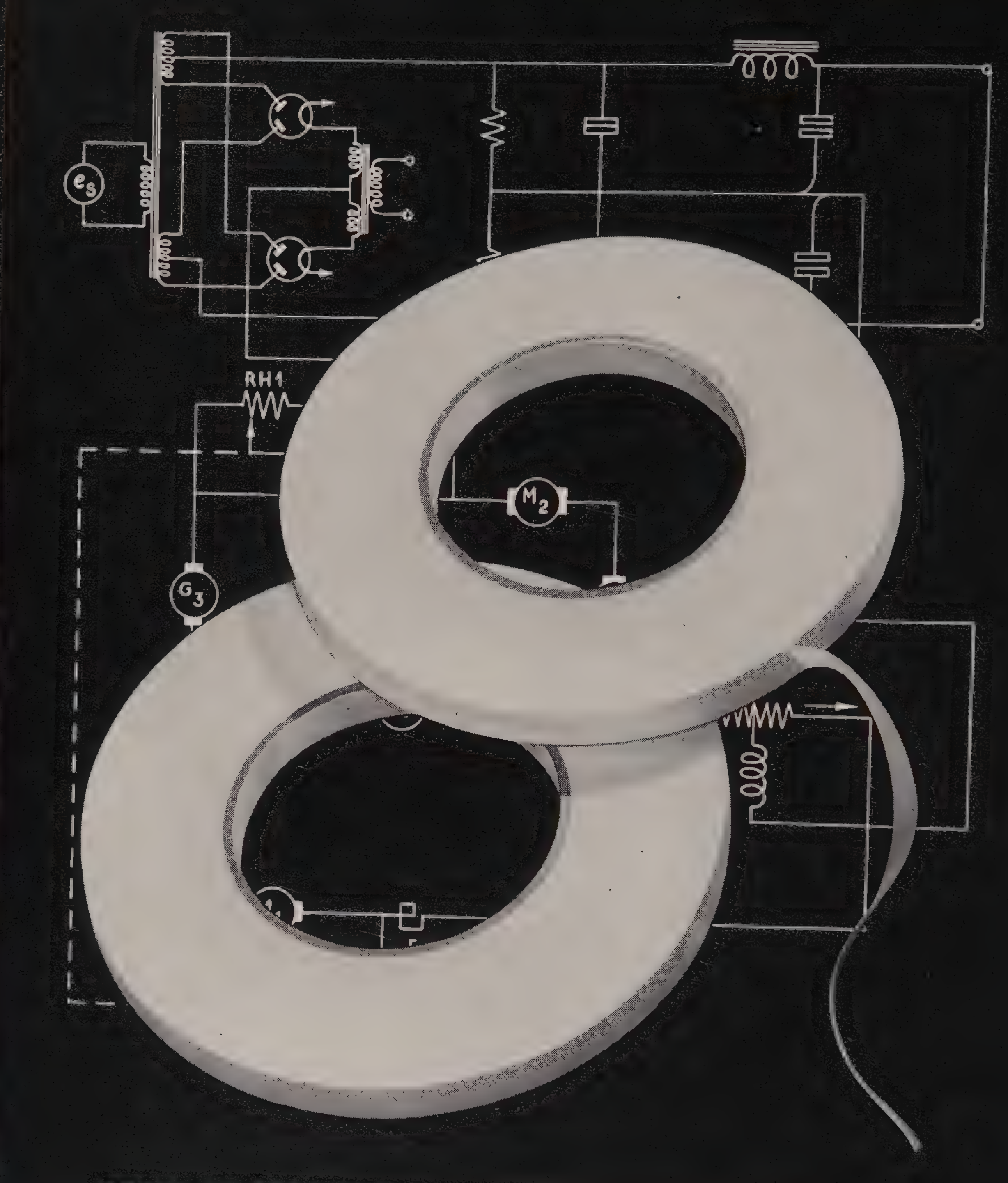

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Commentary

Looking Ahead

THE November issue of *Radio & Electronic Components* will mark its second anniversary and the beginning of its third year of publication. In the past two years, the *Journal* has steadily increased the size of its editorial content and the number of its advertizing pages. It has become obvious, however, that the *Journal* must now take steps to ensure that it does not lag behind in its coverage of the rapid advances now taking place in the electronic components industry.

The most important facet in the production of a technical journal is that of the need to keep in touch with the particular industry with which it is concerned—not only in Great Britain but in other countries throughout the world. Visits to exhibitions, to conferences, and to factories and the subsequent reports on these are a valuable service to readers of a journal in that they keep them informed not only of new developments but also of those which are likely to take place in the future.

Activities such as these are to become an even more important feature of *Radio & Electronic Components*. It has also been decided to form an Editorial Advisory Board and the members of this have already been appointed. Full details of these appointments will appear in our next issue.

The formation of an Advisory Board will certainly enhance the *Journal* both with respect to the content matter and the size.

Although an important part of the function of the Board will be to advise the Editor on various ways and means by which the *Journal* can be improved, an Editor must also depend, to a great extent, on the reactions of his readers to what is published. As far as possible, such reactions are gauged by personal contact. We would stress, however, that we would welcome letters of criticism from readers—whether they be harsh or kind—and it would then be possible to form a clear idea of their exact requirements and action could then be taken to meet these.

If Great Britain joins, as we believe it will, the European Common Market, *Radio & Electronic Components* must then, of necessity, become a truly international journal. The components industry has a great future and we are determined to play a valuable and important role in this; we sincerely hope that readers will be ready to make their own contribution in the way of articles and comment. Manufacturers should also keep in mind that we are always willing to give editorial mention to their new components and to their various other activities in the industry. We are also willing to give advice on readers' problems and if we are not able to answer these ourselves we will pass them on to experts who can. In short, we exist to assist the industry and those connected with it in every possible way—and we intend to fulfil this function for many years to come.

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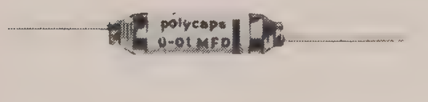

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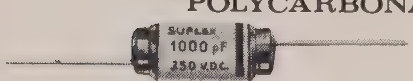

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THE STABILITY OF
PERMANENT MAGNETS

By

A. G. Clegg, M.Sc., Ph.D.

Research Department, English Steel Corporation Ltd.

The changes of magnetization with time of permanent magnets are outlined. The effects of temperatures of −70°C to 700°C are given, and the concept of a reversible temperature coefficient and its compensation are discussed. The influence of alternating magnetic fields, shock and vibration, contact with ferromagnetic material and of nuclear radiation are also outlined.

Introduction

PERMANENT MAGNETS are ideal for applications where the field provided by the magnet is required to be constant. The field can change due to a number of causes, and these will be reviewed in detail in this article.

The magnetic properties of materials can be assessed from their hysteresis loop, the curve relating H the magnetizing field to B the flux density. The loop is measured with the bar under test in a closed magnetic circuit. The second quadrant of the loop, the demagnetization curve, establishes the quality of the material for permanent magnets. Fig. 1 shows a typical demagnetization curve with the principal features indicated on it. Let us examine this curve in detail. When the applied magnetizing field has fallen to zero, the material is still magnetized and the flux density corresponding to this magnetization is called the remanence. As negative fields are applied to the material, the flux density is decreased and eventually reduced to zero. The field required for this is called the coercivity. The value of the product $B \times H$ is a measure of the energy which a magnet can maintain, and its maximum value is $BH_{\max}$.

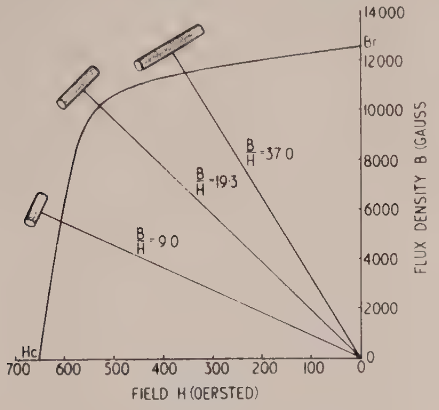

Fig. 1. Demagnetization curve with permeance lines.

If the material is not part of a closed circuit, for example, if it is in the form of a straight bar, the residual flux density, called the residual magnetism (see Appendix), is less than the remanence because of the negative field acting on the bar due to the free poles at its ends. This residual magnetism can be estimated given the dimensions of the bar and the demagnetization curve of the material. The determination of the residual magnetism, by calculation, is only strictly accurate for ellipsoids, but a good estimate of it can be obtained for cylindrical and rectangular bars. Tables for ellipsoids,(1, 2) and cylinders,(3) and formulae for rectangular bars(4, 5) are available to obtain the value of B/H the unit permeance or the demagnetizing coefficient D from which B/H can be calculated using the formula

$$\frac{B}{H}=\frac{1}{D}-1$$

The unit permeance line with a negative slope of B/H intersects the demagnetization curve of the material at the value of the residual magnetism of the bar. The diagram shows three cylindrical bars with their corresponding unit permeance lines. This illustrates how a long bar has a higher flux density at its centre than a short bar of the same cross-sectional area. The most economical design of magnet is when the working point (or residual magnetism) of the arrangement coincides with the $BH_{\max}$ point of the material. Experiments on stability have usually been with three or more bars having different working points, usually above, at and below the $BH_{\max}$ point. It is, of course important, when assessing the stability of a particular magnetic arrangement, to calculate the unit permeance and to interpolate to this value using experimentally determined stabilities of bars.

Table 1 shows the compositions and properties of the

TABLE 1—MAGNETIC PROPERTIES OF PERMANENT MAGNET MATERIALS

Material	Country	Orientation	Nominal Compositions Weight %, Balance Fe Al.	Co.	Cu.	Nb.	Ni.	Ti.	Br(G)	BH_{max} (M.G.Oe)	Hc (Oe)	B/H at BH_{max} G/Oe
Columax	G.B.	Grain & Field	8	24	3	0·8	13	—	13,500	7·5	740	18·3
Alcomax III	G.B.	Field	8	24	3	0·8	13	—	12,600	5·4	650	19·3
Alcomax II	G.B.	Field	8	21	4·5	—	11·5	—	13,000	5·4	580	22·5
Alcomax IV	G.B.	Field	8	24	3	2·5	13·5	—	11,500	4·5	750	15·5
Alnico V	U.S.A.	Field	8	24	3	—	14	—	12,500	5·3	600	20·0
Alnico 400	Germany	Field	9	24	—	—	15	—	11,500	4·3	600	19·9
Alnico VI	U.S.A.	Field	8	24	3	—	15	1·25	10,100	3·8	750	12·5
Alnico	G.B.	Isotropic	10	13	6	—	17·5	—	7,250	1·7	560	13·0
Alnico III	U.S.A.	Isotropic	12	—	—	—	26	—	6,900	1·35	470	13·7
Alni 120	Germany	Isotropic	13	—	—	—	27	—	5,900	1·2	560	9·7
Alni	G.B.	Isotropic	13	—	2	—	26	—	5,600	1·25	580	9·7
Cunife	U.S.A.	Isotropic	—	—	60	—	20	—	5,400	1·3	500	12·3
Barium Ferrtie	G.B., U.S.A. & Germany	Isotropic	Ceramic BaO. $6Fe_2O_3$						2,200	0·9	1,600	1·25
		Anisotropic							3,700	3·2	1,950	1·6

permanent magnet materials mentioned in this article. Details of equivalents and other materials are given by Edwards who gives a detailed tabulation of materials made throughout the world.

Changes of Magnetization with Time

The material of a magnet consists of a great number of domains. Each domain is magnetized in a single direction. In the demagnetized state, the directions of magnetization are random giving an overall magnetization of zero. When a small magnetic field is applied and gradually increased, the direction of magnetization of the domains turn by a variety of processes until, in a saturating field, they are all parallel to the applied field direction. When the field is turned off the magnetization is reduced to the working value. However, some of the domains making up the material are not in true equilibrium. If the material is at a temperature above the absolute zero, the material is in a state of constant thermal agitation. This thermal agitation can cause the direction of magnetization in some domains to change, with a consequent overall loss of magnetization. This process starts to take place as soon as the magnetizing field is removed.

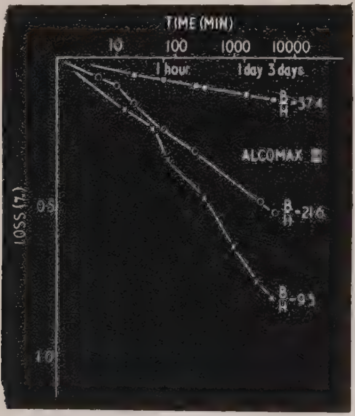

Fig. 2. Loss in magnetization in first three days after magnetization.

Experimental results on the loss of magnetization with time at room temperature on bars have been given by Gould[(7)] and by Kronenberg and Bohlmann[(8)] and on magnet assemblies by Webb.[(9)] The stability of Columax is quite remarkable and Webb found a loss of magnetization of less than two parts in 10^4 over a period of nearly three years. Gould's results on Alcomax III, Alnico and Alni are shown in Figs. 2, 3 and 4. These results were obtained on fully magnetized bars, readings being commenced immediately after magnetization. The results obtained by Kronenberg and Bohlmann on

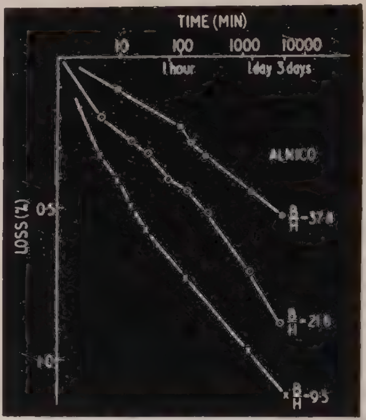

Fig. 3. Loss in magnetization in first three days after magnetization.

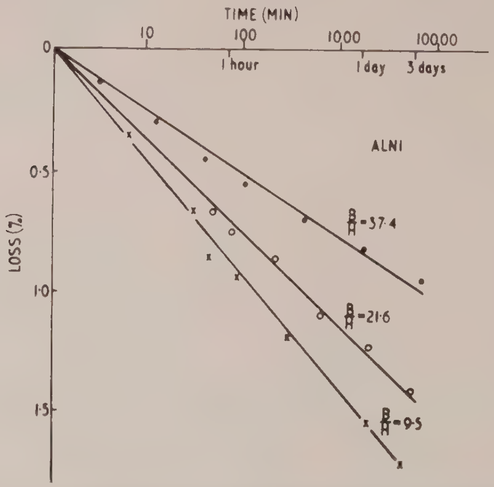

Fig. 4. Loss in magnetization in first three days after magnetization.

Alnico V taken over a longer period were similar to those of Gould on Alcomax III, the linear relationship between magnetization and the logarithm of time being maintained. Webb's results, however, which were probably the most precise, show Alcomax III working near and below $BH_{\max}$ to be more stable than is indicated in the other papers. This may be due to the difference between bars and assemblies, but before this can be definitely stated, further experiments must be made comparing behaviour in the same laboratory.

The above results on changes of magnetization with time show how important it is when measuring stability to determine and state the time between magnetization and the start of a test. This is a point which has not been realized in the past and has made comparisons of results by different workers rather difficult.

Stabilization against changes with time can be made with alternating fields, by heating or by a combination of the two. Gould's results after various stabilization treatments are shown in Fig. 5.

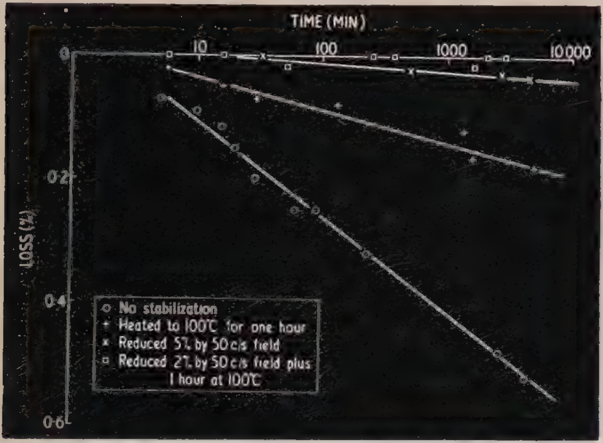

Fig. 5. Flux loss in Alcomax III bar, $B/H = 21{\cdot}6$, after various stabilization treatments.

At elevated temperatures, the changes of magnetization with the logarithm of time were investigated by Kronenberg who found a linear relationship at up to 500°C for Al Ni 120, and up to 300°C for Al Ni Co 400.

Effect of Temperature

(a) Room temperature to 600°*C.*

The changes which are found when the temperature of a magnet is changed can be distinguished as

- (i) Metallurgical or constitutional changes which remain even after remagnetization.
- (ii) Irreversible magnetization losses which remain on returning to room temperature but are regained by magnetization.
- (iii) Reversible magnetization changes which disappear on returning to room temperature without remagnetization. These changes are those which give rise to the reversible temperature coefficient.

A change under (i) will involve a change of the demagnetization curve; this will usually mean different values of (ii) and (iii). The different classes of material will now be considered separately.

TABLE 2—IRREVERSIBLE % LOSS OF MAGNETIZATION AFTER HEATING

Material	Working B/H	200°C	300°C	400°C	450°C	500°C	550°C
Alcomax III	37·4	0·4	0·6	0·75	0·85	1·0	1·15
,,	21·6	0·6	1·0	1·5	1·75	2·0	2·25
,,	9·5	0·75	1·1	1·5	1·7	1·9	2·15
Alcomax II	21·6	0·7	1·2	1·7	2·0	2·4	2·7
Alcomax IV	21·6	0·7	1·1	1·5	1·8	2·1	2·6
Alnico	37·4	2·3	3·2	4·5	5·2	5·6	6·4
,,	21·6	3·2	4·6	6·2	7·2	8·3	9·5
,,	9·5	3·2	5·4	7·3	8·7	9·7	10·8
Alni	37·4	4·0	5·9	8·5	10·3	11·5	14·1
,,	21·6	5·4	8·3	11·6	13·8	15·6	17·2
,,	9·5	7·6	11·1	16·2	19·4	24·1	27·8

Iron-Nickel-Aluminium Alloys: The anisotropic alloys are tempered for a prolonged period at over 550°C to produce their optimum properties. The isotropic alloys are only slightly affected by tempering at 550°C. We should not therefore expect irreversible constitutional changes in these alloys up to this temperature. This has been confirmed by Studders⁽¹¹⁾ and by Clegg and McCaig.⁽¹²⁾

The irreversible losses have been measured by a number of workers. The agreement between these results is good, particularly when account is taken of differences between the initial condition of magnetization of the magnets. The results obtained by Clegg and McCaig are given in Table 2. The irreversible losses are almost linear with temperature up to 500°C. The losses for Alcomax are surprisingly small and show that this type of alloy can be used effectively up to this temperature.

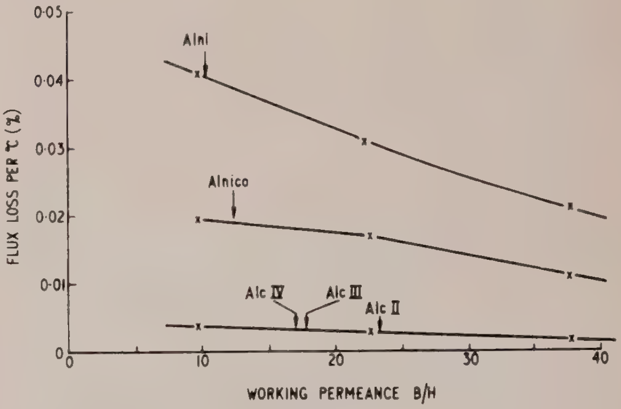

Fig. 6. Flux loss over the range 20 to 300°C. Arrows indicate working point for $BH_{\max}$.

Gould,⁽⁷⁾ using the results of Clegg and McCaig has shown the irreversible flux loss per °C over the temperature range 20—300°C as a function of the working permeance, these results are shown in Fig. 6.

Martensitic Steels: The martensitic hardening steels which include tungsten, chromium and cobalt steels are changed structurally by heating to comparatively low temperatures and are not recommended for use at temperatures higher than 100°C. Changes of magnetization with time and temperature were investigated by Gould (13) and by Whiffen(14) and reviewed in detail by Webb.(15) It is not considered necessary to review effects in these steels as they are rapidly being superseded by more recently discovered materials.

Other Materials: The behaviour of barium ferrite and of Cunife were investigated by Tenzer.(16) Barium ferrite is interesting as it has no irreversible magnetization losses up to 350°C but it shows large reversible changes, these will be mentioned below under temperature coefficients. Cunife has considerable irreversible losses and is inferior in this respect to the other isotropic alloys mentioned above. Platinum Cobalt with Br 6,400; BH_{max} 9·2 M.G.O. and Hc 4,800 has recently been examined by Mintern.(17) Constitutional changes were found at as low as 120°C, and at 350°C after 1,000 h there was a loss of BH_{max} of 8·7%; as this alloy is tempered at 600°C, these changes are quite unexpected. The percentage loss in working flux related to time and temperature is shown in Table 3 below; the working point of the magnet is not given.

TABLE 3—% LOSS IN WORKING FLUX AT ELEVATED TEMPERATURES OF PLATINUM COBALT

Temperature (°C)	Time at Temperature		
	5 min.	2 h	1,000 h
120	3	5·5	7·5
200	16	18·5	22·5
250	21·5	26	29
350	43·5	50·5	51

(*b*) *Reversible Temperature Coefficients*

When the irreversible magnetization losses have been removed by heating, the magnetization will still change with temperature and this magnetization change will be reversible. Reversible temperature coefficients have been determined for a wide range of materials, the values and the corresponding values of unit permeance are tabulated in Table 4.

The values of B/H are in all cases calculated from Evershed's formula $B/H=K(L/A)\sqrt{S}$ where L=length, A=area of cross-section and S=half the surface area of the bar. The value of K is taken as 1·45 which is rather higher than was originally proposed by Evershed.(4)

The temperature coefficient varies with the value of the working permeance and is generally smaller for magnets of lower dimension ratio working well down the demagnetization curve. This has been investigated theoretically by Clegg and McCaig(12) with quite good agreement between experiment and theory, see also McCaig.(18) It is interesting to notice that Roberts and Mitchell(19) who worked on C-shaped magnets for the larger values of B/H obtained lower and less variable temperature coefficients than have been obtained on bar magnets, and it would be useful to have further confirmation of this point.

TABLE 4—REVERSIBLE TEMPERATURE COEFFICIENTS

Material	Investigation	$\frac{B}{H}$	Temperature (% per °C)	Coefficient Temp. Range
Alcomax III	Clegg and McCaig	37·4 21·6 9·5	0·022 0·013 0·013	20 to 200°C
Alnico V	Tenzer	53·6 19·6 12·9	0·022 0·016 0·016	0 to 80°C
Alnico V	Roberts and Mitchell	135·0 32·7 2·4	0·010 0·012 0·0125	0 to 200°C
Alnico VI	Tenzer	53·6 16·8 7·3	0·032 0·020 0·000	0 to 80°C
Alnico VI	Roberts and Mitchell	135·0 32·7 2·4	0·0078 0·0078 0·0052	0 to 200°C
Alnico	Clegg and McCaig	37·4 21·6 9·5	0·019 0·014 0·016	0 to 200°C
Alnico III	Tenzer	53·6 16·8 7·3	0·022 0·022 0·022	0 to 80°C
Alni	Clegg and McCaig	37·4 21·6 9·5	0·024 0·022 0·014	20 to 200°C
Cunife	Tenzer	123·0 15·5 7·3	0·080 0·080 0·080	0 to 80°C
Barium Ferrite	Tenzer	1·15 0·57 0·16	0·190 0·190 0·190	0 to 80°C
,,	Fahlenbrach	2·82	0·185	−200 to 300°C

(*c*) *Temperature Compensation*

When magnets are to be used in sensitive measuring instruments, the change of magnetization with temperature must be compensated. This is achieved by arranging across the poles of the magnet, a magnetic shunt with a reluctance which increases to the required extent with temperature. These properties can be obtained from a number of alloy systems having Curie temperatures not greatly above room temperature. The most usual systems in use are the nickel-iron alloys of approximately 30% nickel, and the nickel-copper alloys of about 70% nickel. The nickel-iron alloys have a higher permeability but the nickel-copper alloys are more easily controlled in manufacture, and the lack of permeability can be allowed for in shunt design. Clark(20) has recently given information about these alloys with particular emphasis on the effect of manufacturing variables on the reproducibility of the permeability variation with temperature.

A Curie point in the region 80 to 100°C will usually give the required variation over the range of temperatures near to room temperature. Ideally the alloy should have a numerically large and appreciably constant temperature coefficient of permeability over a temperature range of about 120°C (i.e. from −40 to +80°C) and it should be structurally stable at all temperatures to which the instrument is likely to be exposed.

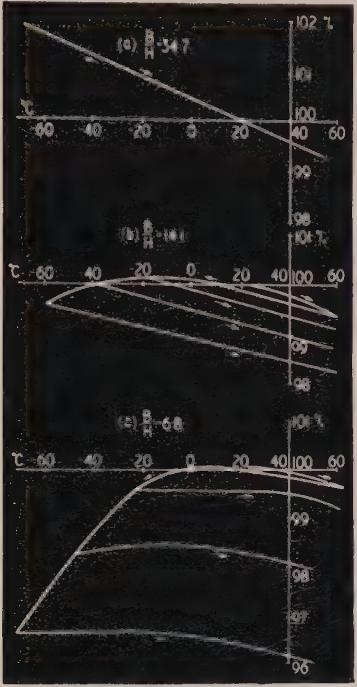

Fig. 7. Temperature variation of magnetization for Alcomax III ellipsoids of varying dimension ratio.

(*d*) *Above* 600°*C*

There is a great deal of interest in the use of magnets up to the maximum possible temperature. Possible applications are the holding of magnetic material during heat-treatment and the use of magnets in high-temperature appliances. In addition, it is sometimes convenient to assemble composite magnets by die-casting or brazing, during which the magnets may be exposed to a high temperature for a short time.

Clegg and McCaig[21] determined the changes of magnetization of rectangular Alcomax bars working at BH_{max} due to temperatures of 650°C and 700°C for times of between 5 min and 21 h. They also determined the changes in the demagnetization curve for similar temperature and time exposures.

The conclusion was that for good stability Alcomax magnets must not be exposed to temperatures higher than 550°C. Short exposures of not more than 5 min at 650°C should not affect performance by more than 2%. Magnets can be used for about 1 h at 700°C and more than 21 h at 650°C provided a performance can be tolerated about 50% worse than that obtained in magnets used at room temperature. A very considerable degree of recovery of properties can be achieved by tempering at 590°C and 560°C if the time at the high temperature (650°C—700°C) is not too prolonged.

(*e*) *Below Room Temperature*

The effect of cooling various materials below room temperature has been determined by the present author[22] and by Tenzer.[16] Interesting phenomena were found for ellipsoids of Alcomax III and cylinders of its near equivalent Alnico V, with low B/H value working well down the curve, see Figs. 7 (*b*) and 7 (*c*). On cooling there was a loss of magnetization. No loss was found for magnets of high B/H working high up the curve, see Fig. 7 (*a*). Clegg established that these effects could be explained by considering the demagnetization curve at room temperature and at the lower temperature. Demagnetization curves at 15°C, −75°C and 180°C are shown in Fig. 8. With bars of low B/H shown by the two lines of lower slope, the flux density must be decreased on cooling. When the flux density is above the intersection of the demagnetization curves its value need not decrease on cooling and in fact it was found to change reversibly with temperature.

Tenzer found similar magnetization changes in Cunife and in barium ferrite. The loss of magnetization of anisotropic barium ferrite is very large. Tenzer[16] shows a loss of up to 25% on cooling to −70°C and returning to room temperature, and similarly Gould[7] mentions a loss of about 30%. These losses can almost certainly be accounted for by decreases of coercivity with reduction of temperature mentioned for instance by Rathenau and others.[23] Isotropic barium ferrite shows only moderate losses unless the working B/H value is very low.

The magnetization of Alnico (G.B.) and Alnico III (U.S.A.) was found to be reversible with temperature on cooling below room temperature. Clegg found that the behaviour of Alnico was in accordance with demagnetization curve changes, the flux density value being higher at the lower temperature for the whole of the curve. Table 5 shows B/H values, changes due to cooling to −70°C and total changes on cooling, and returning to room temperature.

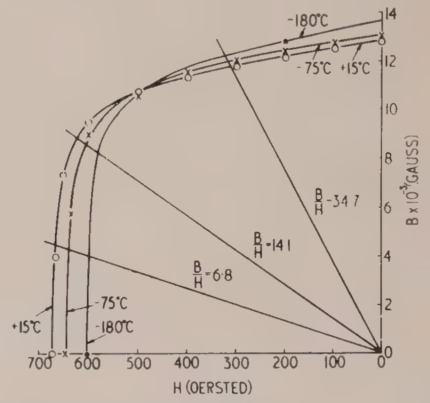

Fig. 8. Demagnetization curves of Alcomax III at 15, −75 and −180°C also showing permeance lines.

Effect of External Magnetic Fields

The effect of alternating magnetic fields has been examined by a number of investigators whose results are very useful for assessing the influence of stray fields and

TABLE 5—CHANGES DUE TO −70°C

Material	Investigation	$\frac{B}{H}$	% Change due to 20°C to −70°C	20°C to 70°C to 20°C
Alcomax III	Clegg	34·7 10·4 6·8	+2·0 −2·4 −3·3	0·0 −3·4 −3·5
Alnico V	Tenzer	53·6 19·6 12·9	+1·9 −2·3 −3·6	0·0 −3·5 −4·5
Alnico VI	Tenzer	53·6 16·8 7·3	+3·8 −1·2 −4·3	0·0 −2·5 −3·4
Alnico	Clegg	14·1 10·4 6·8	+1·7 +1·6 +1·2	0·0 −0·2 −0·2
Alnico III	Tenzer	53·6 16·8 7·3	+1·6 +1·6 +1·6	0·0 0·0 0·0
Cunife	Tenzer	123·0 15·5 7·3	+7·0 −1·0 −1·3	0·0 −8·0 −8·3
Barium Ferrite Isotropic	Tenzer	0·23	−2·5	−17·5
Anisotropic H_c=2,200		2·1	−2·0	−17·0
Anisotropic H_c=1,700		2·1	−10·0	−25·0

the magnitude of fields required for stabilizing purposes. Hadfield(24) checked the demagnetization due to field frequencies of 12·5, 25 and 33 c/s, and found that the demagnetization is less at the higher frequencies due to the reduced field penetration. Generally, however, 50 c/s can be used, except for large sections which may require a lower frequency for full penetration. In order to obtain reproducible results it is necessary to reduce the field to zero over several cycles either by reduction of the current or withdrawal of the magnet from a solenoid. Magnetization changes due to a field of 50 c/s were also measured on ellipsoids of Alcomax III, Alcomax IV and Alnico working at $BH_{\max}$. The results are shown in Fig. 9, included with these is a result obtained by Kronenberg (10) on isotropic barium ferrite. Gould (7) measured the loss of flux for a range of materials in the form of rectangular bars with varying B/H values, the results are given in Table 6.

TABLE 6—FLUX LOSS PER Oe (R.M.S.) DUE TO 50 c/s FIELD ON BAR MAGNETS

Material	Equivalent L/D	B/H	% Loss/Oe (r.m.s.)
Alcomax III	6·0	37·4	0·017
”	4·1	21·6	0·12
”	2·3	9·5	0·14
Alcomax II	4·1	21·6	0·13
Alcomax IV	3·2	15·2	0·10
Alnico	6·0	37·4	0·043
”	4·1	21·6	0·057
”	2·3	9·5	0·071
Alni	4·1	21·6	0·057
”	2·3	9·5	0·071
”	1·33	4·4	0·085
Barium Ferrite (Isotropic)	0·8	2·4	0·003

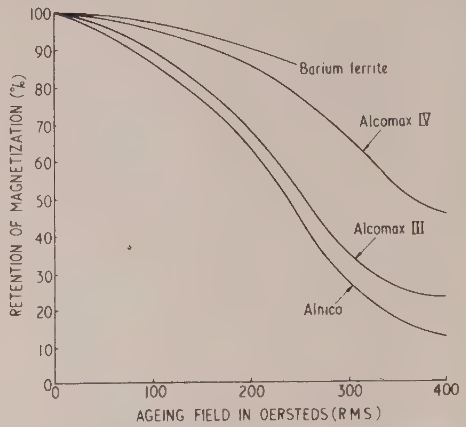

Fig. 9. Loss of magnetization due to 50 c/s alternating field.

These results show that the loss per oersted decreases with increasing coercivity; it was also shown that the initial loss per oersted can be calculated from the values of B and H at the working point and the value of the recoil permeability. The magnetization changes along the preferred and the non-preferred directions in Alcomax were also measured, and it was established that for stabilizing purposes the field direction is not very important provided a sufficient reduction of strength is attained.

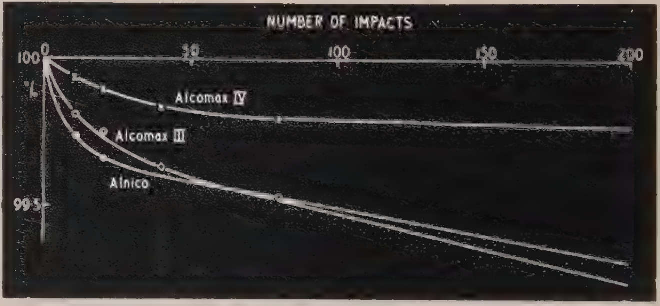

Fig. 10. Flux loss in ellipsoidal bars due to 3 ft. drops onto hard wood, all bars working at $BH_{\max}$.

Effect of Shock and Vibration

Hadfield(24) has examined the effects of shock and vibration on magnetization. Drop tests of 200 impacts from 3 ft. onto hard wood of ellipsoidal bar magnets working at $BH_{\max}$ show a large initial change with little or no subsequent change. Larger losses were found for isotropic than for anisotropic materials, the results are shown in Fig. 10. The vibration tests were at frequencies of 7·8, 16·2 and 19·2 c/s, and the loss was found to be hyperbolic with vibration time—reference should be made to the original thesis for more detailed information.

Gould(7) has reviewed the more recent work on shock and vibration effects in some detail and concludes that the flux changes are normally very small with modern materials, but that there is no sound basis for prediction of losses. Under severe conditions it is advisable to make a practical test of short duration as an indication of the changes likely to take place. Pre-stabilization by an alternating field does not completely eliminate impact or compression losses.

Effect of Contact with Ferromagnetic Materials

The effect here is much larger than is usually imagined. If the surface of a magnet is contacted by a screwdriver or other steel object, the local field around the point of contact is completely changed, usually resulting in a considerable loss of flux.

McCaig(25) has investigated the effect of contact with mild steel on the magnetization of bar magnets of Alcomax and Alnico. Little change was observed in the magnetization when the end of the bar was removed by pulling or sliding off mild steel. When the magnet was laid on its side and pulled off mild steel a reduction in magnetization of about 4% was observed. On the other hand, if the bar was removed by sliding off, the loss of magnetization was 18 to 40% depending on the material and dimension ratio of the sample. The results are shown in Fig. 11. A protective sheath covering the surface of the magnet can be used to prevent such a change. The thickness of protective coating necessary to reduce these losses by a given amount has been studied for Alcomax by McCaig, and for Alnico V by Bozorth(26) with similar results; McCaig's results are shown below:

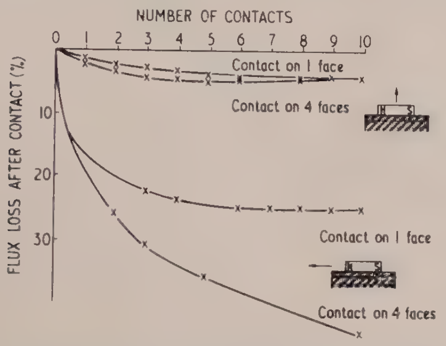

Fig. 11. Flux loss due to side face contact of Alcomax bar with mild steel block, showing difference due to direction of removal.

TABLE 7—EFFECT OF COATING THICKNESS ON THE FLUX LOSS DUE TO SLIDING MAGNET OVER MILD STEEL. ALCOMAX III BAR B/H=18

Coating thickness (mm)	0	0·1	0·2	0·6	0·8	1·48	3·1
% Loss after 10 contacts	39	33	32	16	12·5	5	1

McCaig also studied the effect on the magnetization of bringing two similar magnets together. Two similar Alcomax bars were pressed together with like poles adjacent and pulled apart. After ten contacts using all four faces of each magnet the magnetization had decreased by 24%. The experiment was repeated with unlike poles adjacent, the bars were separated by sliding apart with a motion parallel to their length (the easiest way of separating them). The magnetization was reduced by nearly 60%, again after ten contacts using all four faces of each magnet.

Effect of Nuclear Irradiation

There has been little work published on the effect of nuclear irradiation on magnetization. Fennell, Hancock and Barnes(28) made some rough measurements of magnetization losses in Alni and 6% tungsten steel magnets and found that within an experimental error of 1% there is no loss when irradiated for 1 month by a thermal neutron flux of $1{\cdot}5\ 10^{12}/\mathrm{cm}^2/\mathrm{s}$ and approximately equal epithermal neutron flux. A recent paper by Gordon(28) mentions the irradiation of 36% cobalt steel, Alnicos 2, 5 and 12, Cunico I and Platinum Cobalt by up to about 10^{17} fast neutrons/cm² at 75 to 90°C, and reviews other results. The probable stability of Alnicos 5 and 6 is given as "very good". There is undoubtedly a great deal of interest in this subject and it is expected that, in the near future, much more interesting information will be published.

Conclusions

For a high degree of stability, attention should be paid to the following points:

(1) Constitutional changes should be absent.
(2) Changes with time should be as small as possible.
(3) The effect of temperature, including both reversible and irreversible changes should be low.
(4) Changes due to external fields, shock and vibration should be minimised.

To fulfil these conditions the values of remanence, $BH_{\max}$ and coercivity of the material should be high and the working point of the magnet should be above the $BH_{\max}$ point.

To stabilize against the adverse effects under (3) and (4), the magnet should be subjected to rather more severe conditions than it is ever likely to receive in practice. The effects under (2) can also be minimized by stabilizing treatment.

Appendix

Confusion may arise because the meanings of residual magnetism and remanence approved by the British Standards Institution (B.S. 205/43, Nos. 1260 to 1262) are interchanged compared with those approved in the U.S.A. (A.S.T.M. Designation A127-48). In this article the British Standard has been adhered to, and in particular, remanence is the induction at zero effective field.

Acknowledgment

The author wishes to thank the Directors of English Steel Corporation Ltd. for their permission to publish this review, and his colleagues for helping in the preparation.

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NON-LINEAR RESISTORS

A Review Of Some Single Circuit Elements

By John Dalton, A.M.I.E.E., A.M.Brit.I.R.E.,
Bolton Technical College

A survey is made of various circuit elements which have non-linear current/voltage relationships. The elements discussed are both semiconductors and valves and reference is made to the newer elements such as tunnel diodes.

RESISTORS which obey Ohms Law have a constant resistance over their working range and conduct a current which is proportional to the applied voltage, the direction of current being dependant upon the direction of the voltage. Such resistors have a current voltage characteristic which is a straight line passing through the origin. Consequently the resistance V/I is constant. These characteristics are illustrated in Fig. 1.

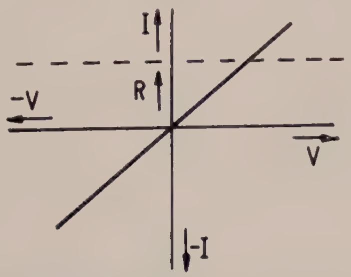


Fig. 1. Current/voltage relationship for a linear resistor. The broken line indicates resistance.

Many circuit elements, however, which are used in present-day practice are useful because they do not obey Ohms Law and have been specifically designed to give a non-linear relationship between current and voltage over the working range of the element. Metallic oxides, silicon carbides, germanium and silicon junction rectifiers, vacuum and gas-filled valves, and iron cored inductors are all examples of circuit elements which, either singly or in combination, are used for their non-linear effect.

Temperature Coefficient

Resistance materials such as conductors and semiconductors exhibit some change in resistance as the temperature is either increased or decreased, the change being a function of the particular material and its dimensions. For pure metals the resistance increases as the temperature rises the relation being expressed approximately for small rises in temperature by:

$$R=R_o(1+at)$$

where R_o and R are the resistances at 0°C, and t °C, and a is a constant for the material called the temperature coefficient of resistance. When R is in ohms (Ω) and t is in °C, the temperature coefficient is in the unit of Ohms/Ohm/°C. This relation is not linear if a wide range of temperature is taken and it is then necessary to add a second and smaller coefficient B such that:

$$R=R_o(1+at+Bt^2)$$

In this case the temperature coefficient is positive. However, in semiconductors the coefficient is negative, that is, the resistance decreases as the temperature rises.

Semiconductors

This important class of electrical conductors is sensitive to temperature, the number of current carriers increasing as the material gains heat. The general characteristics which distinguish semiconductors are negative temperature coefficients, non-linear behaviour, and sensitivity to light, together with a range of resistance which covers approximately 10 Ω to $10^6\,\Omega$. As might be expected from experience with valves, manufacturers have produced a bewildering variety of semiconducting elements, which however, if the transistor is excluded, fall into three main types.

Junction Rectifiers

When small amounts of certain impurities are added to pure germanium or silicon crystals a large number of mobile current carriers are made available either as positive charges (holes), or negative charges (electrons), together with atoms which have lost or gained an electron, and which remain fixed in the crystal lattice. In *p*-type material the majority current carriers are the positive holes, the immobile atoms are negatively charged and in addition there are available a few minority current carriers (electrons) which have been produced by thermal energy. The reverse occurs in *n*-type material which contains electrons as majority current carriers, a few minority current carriers in the form of holes, and positively charged immobile atoms.

If therefore *p* and *n* regions exist in a germanium or silicon crystal it will be found that a potential difference is formed across the junction which separates the two regions, by the presence of the charged immobile atoms. This is simply illustrated in Fig. 2. The polarity of the potential difference is such as to oppose the current flow of majority carriers, but assist the flow of minority carriers across the junction. If this p.d. is lowered by an external supply the majority current carriers are able to cross the junction more easily giving rise to the normal diode characteristic. If on the other hand the p.d. is raised, saturation of the minority current carriers occurs.

The element, therefore, gives a preference to current flow in one direction rather than to the other and is very suitable as a rectifier. The general shape of the characteristic is illustrated in Fig. 3 together with the resistance which may be less than 1 Ω in the forward direction and several hundred megohms in the reverse direction. In fact this type of diode approximates closely to the ideal switch and it is available over an extremely wide range of current and voltage.

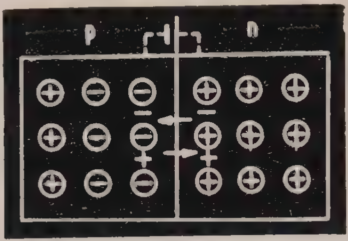


Fig. 2. Presentation of *p-n* junction rectifier under thermal equilibrium. Charged immobile atoms = ⊕; ⊖, Hole = +, Electron = −.

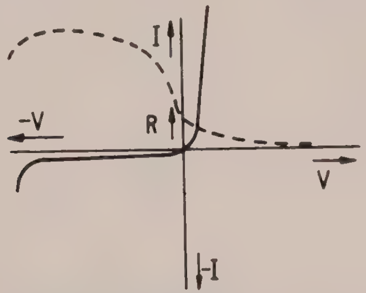


Fig. 3. Current/voltage relationship for a semiconductor junction rectifier. The broken line indicates resistance.

A further useful characteristic of the junction rectifier occurs when a reverse voltage of critical value is applied across the *p-n* junction. Under such a condition the current increases rapidly, the voltage remaining practically constant. This process is somewhat similar to the ionization of a gas with the difference that, in this case, it is the atoms in the crystal lattice which are ionized by impact of fast moving minority carriers, or torn out of the lattice by the intense electric field across the depletion layer at the junction. In either case this effect which is illustrated in the curves of Fig. 4 has led to the production of voltage reference diodes, usually small area silicon units having a low breakdown voltage.

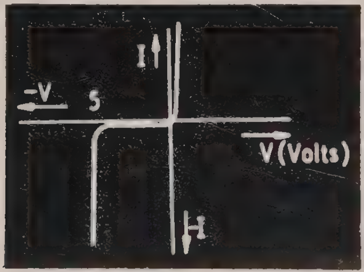


Fig. 4. Current/voltage relationship for a typical voltage reference diode.

By a further modification such as a *p-n* junction heavily doped with impurities on either side of the junction it is possible for a state of breakdown to occur with zero external bias. Consequently a small forward bias is then able to decrease the forward current and the diode thus behaves as a small negative resistance. This is the so-called tunnel diode which is of fairly recent origin and has negative slopes ranging from 10 Ω to 1,000 Ω.

From the characteristics which are illustrated in Fig. 5 it will be noted that the forward current voltage slope is very similar to that of the tetrode valve. This valve was used at one time as a simple oscillator the equivalent circuit being a negative resistance in parallel with an l.c.r. circuit. The tunnel diode can also be used in a similar manner—a suitable circuit being shown in Fig. 6. Although the tunnel diode has the disadvantages of low voltage and power output, the fact that it is of small physical size, has low power consumption, is insensitive to temperature and nuclear radiation and will operate up to very high frequencies all indicate that it is likely to have a considerable future.

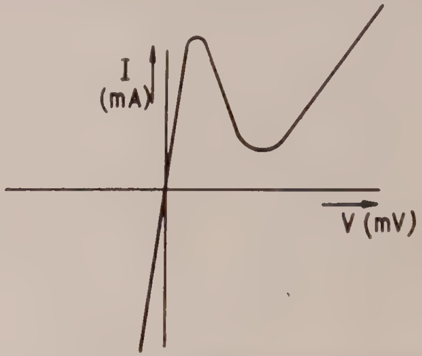


Fig. 5. Current/voltage relationship for a typical tunnel diode.

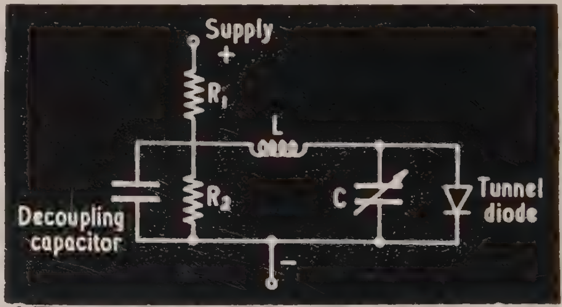


Fig. 6. The tunnel diode in a simple oscillator circuit. Typical values for R_1 and R_2 are 15 Ω and 1 Ω respectively.

Varistors

These are a special class of semiconductor having a relatively high negative temperature coefficient which make use of the rectifying properties of metal, semiconductor contacts. Typical types use mixtures of powdered silicon carbide and clay baked to form a ceramic. The particles form a random distribution of rectifying contacts so that current flows in either direction according to the direction of voltage. The mean value of the forward and reverse curves of these rectifiers for each direction of voltage will therefore give the general form of the characteristic which is designed to vary according to the law $I=ke^n$ where k and n are constants depending upon the mixture, and n lies between 3 and 5. Fig. 7 illustrates the general shape of the characteristic commonly called a Metrosil.

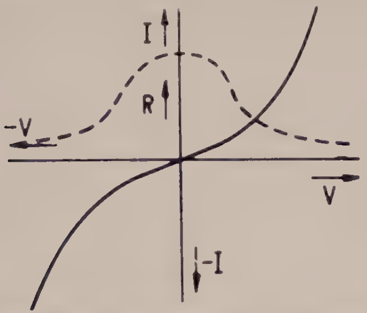


Fig. 7. Current/voltage relationship for a Metrosil. Resistance shown by broken line.

Such a device is often connected in parallel with a linear resistor so that an increased shunting effect may be obtained as the voltage is increased. It then acts as a surge diverter.

A simple use of the Metrosil in this connection is shown in Fig. 8 which illustrates its use in a television receiver to counteract the change of focus that occurs in the e.h.t. stage as the level of mean brightness is changed.

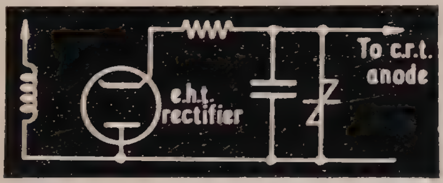


Fig. 8. Application of a Metrosil as a surge diverter.

In the circuit shown it is shunted across the e.h.t. reservoir capacitor so that when the mean brightness falls with reduction in tube current and rise in e.h.t. voltage, the current through the Metrosil increases at a greater rate than the voltage across the reservoir capacitor rises. Similarly, when the beam current increases and the e.h.t. voltage falls, the current decreases through the Metrosil at a greater rate than the voltage falls. The Metrosil thus improves the regulation of the e.h.t. system.

The Thermistor

These make use of the resistive properties of such semiconducting materials as mixtures of manganese, cobalt, nickel and copper, the finished product being in the form of beads, discs, washers, or rods.

When the temperature is low, few free electrons are available and the resistance is consequently high. As the temperature increases the electrons acquire more energy and an ionization effect occurs similar to that previously noted in the *p-n* junction. The thermistor, therefore, has a high negative coefficient and a negative resistance. Its resistance decreases with absolute temperature according to the general expression $R=ke^{n/T}$ where k and n are constants and the temperature coefficient is $^{-n}/T^2$.

As the resistance change of a thermistor is produced by a change of temperature in the semiconductor itself, control of resistance may be obtained either by dissipation of power in the element or by a change in the temperature of its surroundings, and this has led to specific types being produced for either method.

The current voltage curve is illustrated in Fig. 9 the current and voltage increasing together up to a maximum value of applied voltage. Thereafter the current through the thermistor will increase so rapidly that the voltage across it falls giving a negative characteristic over this portion of the curve.

Applications of thermistors are numerous and include temperature measurement, control and compensation, current surge suppression, power measurement, low-frequency oscillators, trigger circuits, and measurement of velocity of liquids and gases.

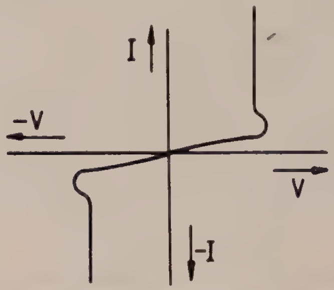


Fig. 9. Current/voltage relationship for a thermistor.

Fig. 10 shows a common method of using the thermistor as a power measuring device in microwave circuits. Either the thermistor or the barretter to be described later may be used. The thermistor is, however, more sluggish in action than the barretter which makes it invaluable in measuring pulse power as its long time constant provides automatic averaging. The principle of power measurement in this manner is as follows. The thermistor is used as one arm of a Wheatstone Bridge supplied through an ammeter and adjustable resistor.

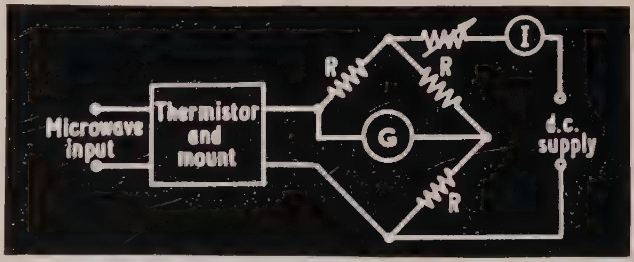


Fig. 10. Method of measuring microwave power using a thermistor.

Without power the bridge is balanced. With power the thermistor resistance changes and balance is restored by decreasing the d.c. power. The change in d.c. power is then a measure of the microwave power.

The use of the thermistor to prevent excessive flow of current when a low impedance power supply is used is illustrated in Fig. 11. The thermistor which is connected between the mains resistor and the heaters has a high resistance on switching-on which gradually falls as the current passing through it causes the temperature to rise.

Vacuum and Gas-filled Valves

The Barretter. Resistance material for linear resistors is operated at comparatively low temperatures and over a small temperature range so that the temperature coefficient of resistance has little effect. The barretter, which consists of resistance wire enclosed in a hydrogen-filled bulb to prevent oxidization, operates at a much higher temperature and has a high temperature coefficient. The characteristic of the barretter illustrated in Fig. 12 is such that for a small increase in current accompanied by an increase in temperature there is a comparatively large rise in resistance tending to compensate for the current increase. An electric lamp has similar characteristics but runs at a higher temperature and burns out more easily.

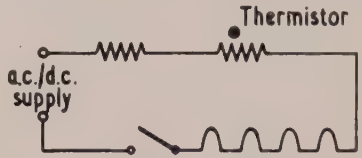


Fig. 11. The thermistor as a surge limiter.

At one time the barretter was an important element in series circuits where it was used to maintain a constant current for small changes in voltage. At the present time however it appears more frequently as a power measuring device in a similar manner to the thermistor.

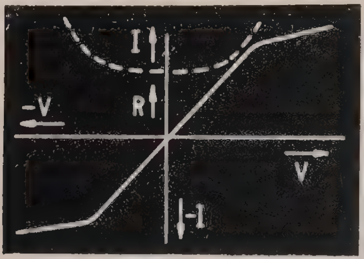


Fig. 12. Current/voltage relationship for a barretter. Resistance shown by broken line.

Cold-cathode Gas-filled Valves. These consist of a glass bulb containing low pressure inert gas such as neon, argon, or mercury vapour together with suitably shaped metallic electrodes. Within the gas a few free electrons exist which gain energy when the electric field between the electrodes is increased until, at a critical value, ionization takes place and the current rises rapidly accompanied by the production of visible light in the form of a glow within the valve. The effective resistance then drops to a very low value.

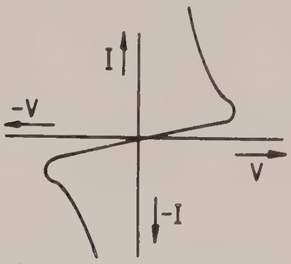


Fig. 13. Current/voltage relationship for a cold-cathode gas-filled valve.

The curve illustrated in Fig. 13 is symmetrical about the origin but may be shifted relative to the current axis by making one electrode emit electrons more easily than the other. If the characteristic is compared with that of the barretter it will be noted that over a certain portion of the curve the cold cathode valve has a large increase in current for an almost constant voltage, exactly opposite to the barretter. For this reason it is widely used to provide a suitable reference voltage.

The Vacuum Diode. This is a unidirectional device which only passes an appreciable current when the anode is positive with respect to the cathode. A small current flows with zero anode voltage due to the emission of a few fast moving electrons from the cathode but the current is cut off completely by a small negative voltage.

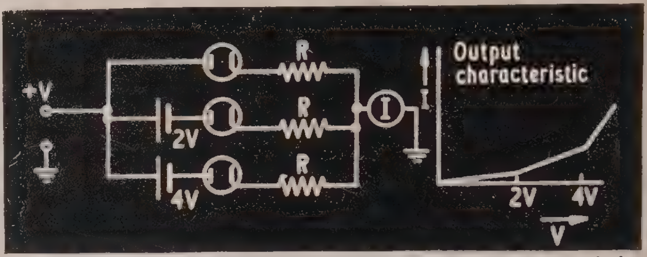


Fig. 14. Diode function generator together with output characteristic.

The vacuum valve is still widely used as a rectifier and a switch, and more recently has been connected with circuits that provide a variety of non-linear relationships similar to some of the single circuit elements discussed, but without their built in characteristic.

These diode circuits known as function generators can be arranged to simulate a given non-linear function to a high degree of accuracy, provided enough diodes are used. Such an arrangement might comprise a number of diodes, biased to different values of voltage and connected in parallel, so that as the input voltage is increased, each diode in turn becomes conducting or non-conducting and either decreases or increases the voltage current curve. This is illustrated for the case of three diodes in Fig. 14.

Iron-cored Inductors. For the purpose of a.c. circuit calculations it is assumed that iron-cored inductors follow Ohms Law but, in practice, due account has to be taken of magnetic saturation which is sometimes used to produce a specific non-linear effect. Fig. 15 illustrates the characteristic of an ordinary iron-cored inductor.

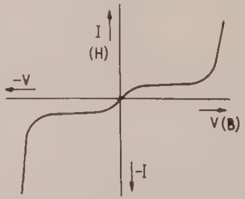


Fig. 15. Current/voltage relationship of iron-cored inductor.

An extreme example of this effect is the saturable inductor which offers a high impedance below saturation

Continued on page 744

Correspondence

The Editor,
Radio & Electronic Components

Some aspects of component reliability data

Dear Sir,

An increasing amount of information on electronic component reliability is appearing in technical literature. Much of this information has a strictly limited usefulness and by extrapolation or otherwise can result in completely inaccurate predictions. First consider the common method of presenting reliability data. Failure rates for components in a large equipment or a number of equipments are quoted in % per 1,000 h or per annum. Generally all types of capacitor or resistor, etc., are lumped together; environmental or circuit conditions are rarely quoted and the resultant failure rates can vary widely. The extent of this variation is, perhaps, not generally known and Table I gives maximum and minimum failure rates obtained in this country. It will be seen that a ratio of maximum to minimum of 35,000 exists for resistors. It is interesting to compare these with similar figures in the U.S.A.⑴ where the maximum ratio is 60,000 for capacitors, the ratio for resistors being 400. One may be tempted to draw a number of conclusions of which the most likely is that the United Kingdom makes the most consistent capacitor and the U.S.A., the most consistent resistors. In the writer's opinion the obvious conclusion is that for the majority of purposes data of this nature is virtually useless.

TABLE 1—MAXIMUM AND MINIMUM FAILURE RATES (GREAT BRITAIN)

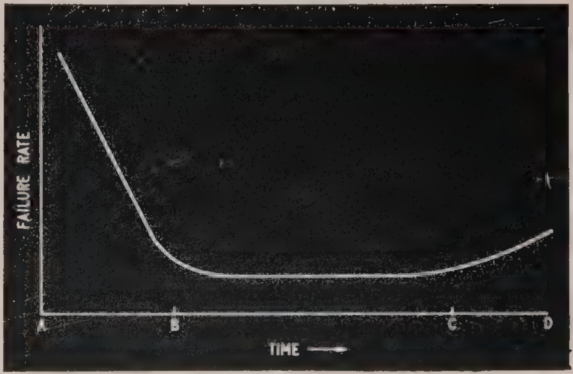
Component	Published failure rates per 1,000 h (%)		Ratio Max/Min
	Minimum	Maximum	
Capacitors (all types) ...	0·000125	0·135	73·5
Resistors (all types) ...	0·000125	4·5	35,500
Relays	0·0375	0·8	21
Transformers ...	0·104	2·25	22
Switches	0·024	0·8	32

Consider next Table 2. Here capacitor and resistor failure rates have been broken down into their various types. Again the ratio of maximum to minimum is enlightening, and from the figures one may be tempted to conclude, for example, that electrolytic capacitors are more consistent than paper types. In this case, it is not only essential to quote the environmental and circuit conditions but also the manufacturer. This point was well illustrated by the tests made at the Royal Radar Establishment on resistors and referred to in the recent I.E.E. Symposium. In the discussion which followed, it was pointed out that in the case of carbon film resistors only one of those of a certain manufacture had failed. Tests made by the writer have, in fact, indicated that under severe climatic conditions this particular make of carbon film resistor has proved superior to the metal oxide and metal film types.

TABLE 2—CAPACITOR AND RESISTOR FAILURE RATES

Component	Published failure rates per annum (%)		Ratio Max/Min
	Minimum	Maximum	
Capacitors			
Paper	0·06	1·9	31
Ceramic ...	0·04	0·45	11
Mica	0·03	0·18	6
Electrolytic ...	0·3	1·17	4
Resistors			
Carbon Composition ...	0·0006	0·65	1,080
Carbon Film ...	0·001	0·73	730
Wire Wound ...	0·017	0·55	30

It has been suggested⑵ that the failure rate curve for many components follows the familiar bath tub shape (see figure). Assuming only one mechanism of wearout *AB* corresponds to early failures, many of which may occur during the running-in period, *BC* to the useful working life and *CD* to the wearout period. Failure rates quoted in % per 1,000 h without indicating the starting



point may or may not include portion *AB*. If, in fact, they start from point *B* and the data are used from point *A* then, certainly over the first few thousand hours, results may be far from those estimated.

There may be, and probably is, a tendency to look on all components approved to a particular Service specification as being equally reliable. This is not necessarily true as far as life is concerned. In a paper by J. M. Farrier(1) he quotes the case of 3 manufacturers whose products all met the 1,000 h life test specified in the appropriate MIL specification. However, on continuing the test to 5,000 h their behaviour was considerably different. Thus, unless the specification includes a life test, accelerated if necessary, corresponding to the required life of the component, it is necessary to know the individual behaviour of the components of different manufacturers.

It is essential to appreciate that information of the type considered here generally applies to a large number of components of randomly distributed types or makes and therefore cannot be applied to smaller numbers or to an equivalent number of single types or makes. For example, it may be that out of say 1,000 capacitors 20 failed and a failure rate of 2% was quoted. If however these 20 were all of one type of which only 40 were used a different picture is presented.

With standard logic circuits or bricks it may often be possible to construct an equipment to do a certain job in a number of ways using different bricks. Reliability information, as previously mentioned, can only be applied to large numbers of components and consequently an estimation of reliability can only be made on the complete equipment regardless of the arrangement or type of bricks. It is more than likely, however, that different arrangements of bricks would result in different overall reliability figures which could only be obtained if the reliability of the individual bricks was known. Since these bricks contain only a relatively small number of components it is essential to know the reliability of individual components if maximum overall reliability is to be obtained at minimum cost and effort.

Finally, the writer, in company with other engineers, would like to make a plea for more detailed information on any reliability figures which are published. For his part he is extremely reluctant to quote or use any data unless full information is available.

The writer is indebted to the management of British Telecommunications Research Ltd. for permission to publish this letter.

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NON-LINEAR RESISTORS

Continued from p. 742

to the flow of alternating current because the current produces a changing flux which induces, in the coil, a back e.m.f. opposing the applied voltage. However, when the core is magnetically saturated the flux linking the coil can no longer be increased by an increase in current so that the induced e.m.f. and thus the impedance falls to a low value.

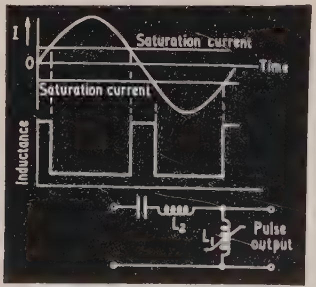


Fig. 16. The use of a saturable inductor for production of pulses.

By the use of this effect it is possible to obtain satisfactory pulses from a sine wave and this is illustrated in Fig. 16. If the components are arranged so that the resonant frequency of the circuit is close to the resonant frequency of the incoming sine wave the current is large and hence the inductor changes quickly from the saturated to the unsaturated condition and *vice versa*. Under these conditions the impedance of L2 also changes quickly and a large voltage pulse is developed at the output.

Conclusion

The examples discussed concern circuit elements which have non-linear current/voltage relationships. They are used in an immense variety of circuits for this fact alone. However from the characteristics illustrated it may be noted that portions of the curves are sometimes linear, sometimes exponential, and sometimes subject to an abrupt change in slope. It is therefore a matter of deciding, what are the limits of current and voltage that are to be used with a particular element in a given circuit. It is then possible to decide the most suitable method of analysis, linear, non-linear or graphical.

BATTERY Research and Development

By Dr. M. Barak

Central Laboratories of The Chloride Electrical Storage Co. Ltd.

A survey is made of research and development now being carried out on batteries at the Central Laboratories of The Chloride Electrical Storage Co. Ltd. The fundamental principles of battery manufacture are discussed together with the problems of improving battery efficiency, life and the reduction of weight.

THE INSATIABLE DEMAND FOR POWER

THE prosperity of a country is closely linked to its industrial development and this in turn is often measured by its consumption of electric power. During the past two decades there has been a phenomenal increase in plant for the generation of electric power, culminating in several countries in the use of the vast forces of atomic energy for this purpose. Side by side with these developments of huge stationary power plants, the need for relatively small supplies of localized or portable electric power has also steadily increased, power for driving commercial vehicles and trucks used in the handling of goods and materials on the roads and in the factories, power for special purposes in aeroplanes and ships, for lighting and air-conditioning equipment on trains, for driving mining locomotives and for miners lamps; for starting and lighting motor vehicles of all types, for standby supplies to operate switches and other equipment in larger power stations; for emergency lighting in hospitals, cinemas and other public buildings; to energize radio equipment in rockets, guided missiles and satellites. Many of these increased demands arise from the extension of existing uses but others come from new and novel developments, hardly contemplated 25 years ago. For many of these portable uses, weight and volume are at a premium but in spite of the ceaseless search for lighter and more efficient systems, storage batteries have continued to supply the main demand.

Battery manufacturers are fully alive to the need to reduce weight and to increase efficiency, and in the Chloride Laboratories these problems are under constant attack by the fundamental as well as the applied approach.

Substantial improvements have already been made. The standard motor car battery of today gives over 20% more power for the same weight than its counterpart of about 10 years ago, and it is true to say that the average life of a battery on a motor car, which today has to operate more electrical components than ever before, is considerably longer. In the traction field even more spectacular improvements have been made. Modern batteries for electrically propelled vehicles are at least 30% lighter and less bulky for the same output than they were even 5 years ago. Stationary batteries for special work such as switch-tripping and emergency lighting give almost 2½ times the output in the same volume of their pre-war counterparts. The lightest lead-acid aircraft battery of today has about 50% more power per unit of weight than batteries of 20 years ago.

Modern alkaline batteries for electric traction have increased in life and are 15% more powerful than their predecessors. About 25% more power is obtained from the modern alkaline diesel starting or switch-tripping battery than could be obtained from similar batteries of the same weight only 10 years ago.

Every advance of knowledge opens up new and more fundamental questions to be investigated. Modern invention, the conquest of space and expanding human endeavour in many directions bring demands for batteries of unconventional design that will fit into small or odd-shaped spaces and stand up to exacting conditions of temperature and stress. Meanwhile the improvement of standard types must go on. Battery research and development today calls for an enormous concentration of scientific effort.

The Chloride Electrical Storage Company, realizing the importance of keeping up-to-date with all new developments to meet the increasing competition throughout the world, has built and equipped these new Research Laboratories in order to ensure its continued position of the largest battery manufacturing organization in the British Commonwealth.

FUNDAMENTAL RESEARCH

The electric current which lights a lamp-bulb or drives an electric motor is the manifestation of the flow of electrons in a conductor. Electrons are minute, negatively-charged particles which form part of the atoms, from which all substances are built. These electrons oscillate in various numbers around the heavy, central, positively-charged nucleus which gives each atom its chemical identity. This orbital movement resembles the movement of the planets around the sun. Some of the external electrons can be detached under certain conditions and if suitably guided into a conductor, they set up an electric current.

The chemical reactions which produce the electric power in a battery depend upon the transfer of electrons between the solid electrodes and the liquid electrolyte. In the Electro-Chemical Laboratory fundamental research in electro-chemical reactions is carried out.

The chemical reactions which produce the electric power in a battery depend upon the transfer of electrons between the solid electrodes, or plates and the liquid electrolyte. The electrolyte conducts the current in a different way from the metallic conductor in the external circuit. The conductivity of the electrolyte is due to its dissociation into ions. These are positive, or negatively charged particles which have a deficiency or an excess of electrons and move towards the negative or the positive electrode respectively. Here the ions are discharged, and the rate of transfer of electrons is determined by the vigour of the chemical reactions which take place at the surface of each electrode.

Each of the two electrodes, that is the positive and negative plates, exerts its own characteristic electrical pressure or potential and the electromotive force or voltage of the couple is determined by the numerical difference between these two potentials. This electromotive force, or e.m.f. as it is generally written, has sometimes been likened to the head of water in a tank. The greater the head of water, the faster the flow will be when the tap is opened. In an analogous way, in choosing a battery system, there are advantages in selecting electrodes with high potentials and this is one cogent reason why the lead-acid battery remains so widely used and continues to occupy a large proportion of the research facilities. The e.m.f. or voltage of the lead dioxide/sulphuric acid/lead cell is about 2·0 V as compared with about 1·2 V for the nickel oxide/potassium hydroxide/cadmium cell. This means that only 3 lead/acid cells are necessary to produce a battery voltage equal to that of 5 alkaline cells. Batteries employing nickel/cadmium (or iron) electrodes in an alkaline electrolyte, however, also have a number of applications and their great durability gives them a particular advantage in certain fields. Fundamental studies of these electrodes are also in progress.

The old problem of weight is under constant investigation. Unfortunately nature has endowed lead with its objectionable but immutable density, just as she has endowed it with so many other properties that make this metal almost pre-eminent for reversible electrodes. It is the insolubility of the reaction product, lead sulphate, which on the one hand gives these electrodes their high degree of reversibility, and on the other restricts their electrical capacity. Life and capacity per unit weight are in fact directly related, and this applies also to other reversible systems. The output per unit weight of the nickel/cadmium battery for example is no more favourable. Though the materials are lighter than lead, this is offset by the lower cell voltage of this couple.

Research is also being actively pursued on other electrode systems, in particular that using silver oxide and zinc electrodes with caustic potash electrolyte. This can give about five times the output in relation to volume and weight compared with either of the other two systems; but it has several serious disadvantages. If its life and reliability could be improved this couple might find much wider applications.

The reactions which take place in all battery systems are known as electrolytic "redox" or reduction-oxidation reactions. Reduction takes place at the positive and oxidation at the negative plate. Interpreted in another way, oxygen is produced in an ionic form at the positive and oxidizes a reductant at the negative. Fundamentally this is the same sort of electrochemical reaction as that which takes place in a fuel cell and it is a logical step, therefore, to extend the research on battery systems to a study of the basic reactions in fuel cells.

For checking the purity of alloys—to which their behaviour under test must always be related—there is a medium quartz spectrograph in constant use in the Metallurgical Laboratory.

Work is in progress on several aspects of fuel cells. One phase of this work concerns the factors which cause oxygen gas to ionize and this involves a study of the effect of catalysts, gas pressure, temperature of the electrolyte, internal surface area and pore size of porous electrodes, made from various materials, and so on. The use of air as a source of supply of oxygen is also being tested. Another phase concerns the oxidation of gaseous fuels and as a first stage, this work is being concentrated on the use of hydrogen. The possibility of using liquid fuels is also being examined. Hydrazine has shown promise though this fuel would be expensive and other cheaper liquid fuels are being tested. Finally some experimental work is being carried out with metallic fuels such as zinc and iron.

INCREASING EFFICIENCY

The electrical efficiency of a battery depends upon a free and continuous flow of electrons between the electrodes or plates and the electrolyte. The flow of electrons is in turn governed by the rate of the chemical reactions taking place at each electrode. Taking the lead/acid battery as an example in which the positive and negative active materials are lead dioxide and spongy lead respectively, and the electrolyte is sulphuric acid, the accepted chemical reactions are as follows:

At the positive plate

$$PbO_2 + SO_4^{=} + 4H^+ + 2e^- \xrightleftharpoons[\text{Charge}]{\text{Discharge}} PbSO_4 + 2H_2O$$

At the negative plate

$$Pb + SO_4^{=} \xrightleftharpoons[\text{Charge}]{\text{Discharge}} PbSO_4 + 2e^-$$

It is clear that as the battery is discharged, the active materials of both plates are converted to lead sulphate while the electrolyte becomes more and more dilute due to the removal of sulphate ions.

Analysis of a vast number of samples of material of many kinds is part of the day-to-day work of the Chemical Analytical Laboratory. For investigating the complex mixture of gases evolved during charge and discharge, a special chromatographic apparatus, with automatic recording mechanism, has been devised, which can instantly detect amounts of hydrogen (for instance) as low as five parts in ten million.

Lead sulphate has a very low electrical conductivity and the formation of this substance in the active material causes the phenomenon referred to as polarization. Another form of "concentration polarization" takes place as a result of the dilution of electrolyte and it is obvious that this effect becomes greater, the greater the current which is drawn from the battery.

The efficiency of the battery in terms of the output in watts per unit weight of the active material is thus dependent on the degree and the nature of the polarization, which takes place on discharge. Vigorous efforts are being made to improve the efficiency of the active materials in both lead/acid and nickel/cadmium batteries by a better understanding of the factors affecting the polarization of the active materials. Information on the mechanism of the polarization which occurs during discharge is being gained by measuring the dynamic resistance of electrodes of all types in a wide range of conditions including both acid and alkaline electrolytes. Studies of the oxidation and reduction reactions on lead electrodes and of the respective effects of polarization and the rate of growth of lead sulphate crystals are in hand to produce information which will lead to greater efficiency in lead/acid batteries.

A regular, steady and flexible supply of power for the test circuits comes from a big Chloride battery with a capacity of 6500 A-h floating on a mercury arc rectifier at 115 V. Tappings are taken at every three cells, each giving a nominal 6 V, and connections can be made via a distribution board to the test benches at any voltage level.

To overcome polarization it is advantageous to have highly porous electrodes with a large internal surface area; such electrodes are generally made from finely divided oxides. The size, shape and distribution of particles in the oxide all affect the porosity of a plate, and these characteristics are currently being studied by the use of a special photoelectric-sedimentometer.

These factors are examined with others, such as the structural changes in the porous matrix, due to the chemical changes taking place during charge and discharge. Attempts are then made to correlate the overall effects with battery performance.

To increase the efficiency of lead negative plates organic materials or expanders are added. Accurate detection of organic substances in small quantities is greatly assisted by modern techniques of spectrophotometry and polarography. Micro-analysis is now being used to reveal the molecular structure of complex organic compounds.

One particular application that calls for basic investigation of organic materials is the manufacture of a lead/acid battery which can be stored indefinitely and put into action simply by filling with electrolyte. In this, the negative electrode must be protected against oxidation by some suitable substance. A study has been made of various organic anti-oxidants, particularly with a view to establishing the relationship between their basic structure and chemical properties on the one hand, and on the other, their effectiveness in preventing the oxidation of lead.

Another interesting development is a particular type of alkaline battery in which the grid consists of sintered nickel and the positive and negative active materials are held in the fine pores of the nickel. These plates can be made considerably thinner than the "pocket" type of the conventional alkaline battery. Cells of this kind have special merits where high wattages are required.

Fundamental studies of the polarization of these porous plates has enabled special designs to be made for use in guided missiles.

REDUCING WEIGHT

Work is continually in progress on methods of reducing the weight of storage batteries. Many components must be taken into consideration. There are the plates themselves, consisting of the active material and the metallic grid, which serves as the support for the active material as well as the means of conducting the electrons away to the external circuit. There are also the electrolyte, the separators, the containers, lids and sealing compound and finally the posts and inter-cell connectors which must be substantial enough to carry the heaviest currents which the battery may be expected to supply, and sufficiently robust to withstand any vibration or shocks.

Mention has already been made of the way the efficiency of the active materials may be improved by a study of the factors affecting its polarization. The plate grids serve an essential function in the behaviour of the battery, but their weight may be as high as 75% of that of the active materials and so far as the chemical reactions are concerned, this must be regarded as dead weight. A continual search is therefore being made for better alloys from which lighter and more durable grids can be cast, as well as for better designs of the supporting grid.

In the case of the lead/acid battery, the grids are cast in alloys which are basically lead, to which antimony is added as a hardener. Other metals may, however, be added in small amounts to confer special properties such as a greater resistance to anodic oxidation or a higher tensile strength, greater stiffness or greater ductility and so on.

The laboratories are constantly investigating all the complex factors of grain structure in metals and their influence on the physical and chemical behaviour of alloys, such as tensile strength, hardness, creep resistance, and resistance to anodic attack in sulphuric acid.

Spectrographic techniques greatly accelerate the analysis of lead alloys, and also of the various metals employed in alkaline battery manufacture, and the many other materials used in different departments of the laboratories.

In the nickel/cadmium alkaline battery, on the other hand, the plate structure is different. In the conventional battery, the active materials are contained in compressed pellets held in envelopes made from perforated nickel-plated steel strip. In the sintered type of plate the porous sintered nickel plaque forms the grid to support the active materials which are introduced into the porous grid by impregnation of concentrated solutions.

In both types of construction means of reducing the weight are continually under review. In the case of the sintered plate for example, the particle size of the nickel powder can affect the porosity of the sintered plaque and this in turn has a bearing on the weight of the plate.

The weights of the electrolyte must also be kept to a minimum and studies of the factors affecting the diffusion of the electrolyte through the separators and into the active materials provide useful information on this aspect.

Finally the weights of the containers and the possible uses of new plastic materials must always be kept under examination.

EXTENDING BATTERY LIFE

Under normal working conditions the life of a battery may be dependent on several factors. In the case of the lead/acid battery, the positive grids may break down through persistent anodic corrosion. Alternatively the active materials may gradually work out of the grids and fall to the bottom of the cell. Some failures may be caused by penetration of the separators by active material, which ultimately causes a short circuit. Failure is sometimes caused by the ingress of certain metallic impurities which may cause premature sulphation of the active material or corrosive impurities which cause enhanced attack on the plate grids.

Limitation of life of an alkaline battery is a little more complicated. Densification of the active material may arise or in the other extreme, accentuated shedding. Absorption of atmospheric carbon dioxide by the electrolyte may be a factor and the ingress of certain other impurities must be avoided. In the sintered plate assembly the life of the battery is closely related to the performance of the separator which is, in this case, used in extremely thin sections.

All these aspects are under review. The effects of impurities need particularly close watching in the electrochemical processes of a storage battery, where a minute trace of certain substances can have a decisive influence on performance and length of life. Rigid specifications must be laid down for the purity of all chemical components. To establish permissible limits the

Analytical Section carries out a series of controlled experiments, collaborating closely with other departments engaged on electrical or physical tests.

The Central Laboratories receive a multiplicity of samples for analysis which may be concerned with problems connected with the quality of local supplies, whether of water, sulphuric acid or lead alloys and lead oxides for platemaking. They have collaborated with the British Non-Ferrous Metals Research Association in a search for new methods of analysing lead and lead-antimony alloys and have developed original techniques which are now accepted as standard practice.

There are many organic components which have an effect upon battery performance and life, such as plastic and cellulose materials, and organic materials of various kinds, all of which are constantly under examination involving a critical analysis of materials at present in use. Basic research is also carried out into the properties and behaviour of new materials which may have any potential relevance to battery application.

Batteries are used in a variety of climatic conditions, tropical and arctic as well as temperate. The chemical reactions which take place are accelerated at high temperatures and retarded at low temperatures. Tests of the durability and performance of the components and materials used are carried out at temperatures over the whole range from 60°C to minus 60°C.

In the alkaline field the active materials in batteries which have failed prematurely in service are being systematically examined by X-ray techniques to see whether their behaviour can be related to changes in their crystal structure. Electrochemical measurements are also being made by means of oscilloscopes, in an effort to isolate the factors causing premature polarization.

RESEARCH APPLIED

The lessons learnt in fundamental research are later applied in a practical way in long-term development projects. A succession of advances spread over the last thirty years has already produced a remarkable improvement in all types of lead/acid battery. But much remains to be done.

Every detail of the battery must be kept under review for possible improvements in design, material, or method of manufacture. Moreover every application—for cars, aeroplanes, lifeboats, trains, industrial trucks and locomotives, submarines, portable radio, stationary standby service and many special uses—presents its own particular problems.

A special technique has been worked out to observe the performance of plates while conditions in the battery—such as temperature, electrolyte concentration, and internal resistance—are strictly controlled. Measurements of gas evolution in varied conditions have provided valuable data on the efficiency of the charging operation of lead/acid batteries.

Studies of gas evolution at electrode surfaces have also supplied useful information in connection with the development of sealed nickel/cadmium cells which require little or no maintenance in service.

After the basic research has been carried out in the Chemical Laboratories the results are applied in small pilot plant production of plates and complete batteries of all types. For this purpose a full range of equipment is available for all of the factory operations of casting of grids, pasting of plates and forming and drying under various conditions.

Before any new development can be passed for production it must be carefully proved in an extensive and varied selection of tests, according to the concept which it embodies and the conditions of service for which it is designed.

Some very unusual testing problems were met and solved during the development of a range of batteries for electronic equipment in guided missiles, meteorological balloons, and other highly specialized uses. Such batteries were based on various unorthodox electrochemical couples, including some using water as an electrolyte.

The basic work on the principles of operation of fuel cells is now being applied in the construction of multicell fuel batteries. Two 500 W batteries have been made, both using oxygen, in one of which hydrogen serves as the fuel and in the other, liquid hydrazine. These units operate at about 6 V or 0·5 V per cell and are being used to study problems of fluid flow and circulation of both fuel and electrolyte.

The next stage in this work will be to build larger units embodying the improved principles evolved from these tests.

FARNBOROUGH

English Electric Lightning Mark 2

AIR SHOW 1961

A General Survey

IT IS very easy to be overwhelmed by the surface glamour of this popular annual event. Everything about it is on a grand scale with the impressive rows of aircraft lined up on the tarmac; the roar of their engines as they fly overhead; and the size of the exhibition itself. The 1961 Show was, in fact, the 22nd in the series presented by the Society of British Aircraft Constructors since 1932 and was the 14th time it had been held at the Royal Aircraft Establishment.

The exhibition pavilions were divided into two main parts—one concerned with equipment exhibited by aircraft and engine manufacturers and the other with parts, accessories and materials.

The latter of the two was concerned mainly with light and heavy aircraft engineering, instrumentation and flying equipment generally. Electronic components were somewhat overshadowed by their, visually at least, more impressive co-exhibits, and this survey must, of necessity, be little more than an outline of those products which were noticed and considered of interest to readers of this *Journal.*

The Exhibits

Although **Ferranti Ltd.** showed a wide variety of ceramic-to-metal seals, silicon rectifiers and silicon transistors, there was little among these items which could be considered particularly novel. The same comment could apply to the impressive range of components with applications in the aviation electronics industry exhibited by **Standard Telephones & Cables Ltd.** On this stand, the main emphasis was placed on the use of STC valves in aircraft.

There was, however, an interesting new development on the stand of **Marconi's Wireless Telegraph Co. Ltd.**—this was the experimental solid-state diode parametric amplifier and mixer.

This device is the outcome of one of a series of investigations which are currently being carried out at the Marconi Research Laboratories in which various possible alternatives in microwave low-noise amplifiers are being systematically explored.

The importance of this combined amplifier and mixer lies in its excellent low-noise characteristics and also because one such unit can replace at least three valved stages in a conventional receiver. Experiments with such a device incorporated in a Marconi Type SR 100 radar transmitter/receiver (aerial temperature 120°K) have shown it to enhance the overall noise factor from approximately 7 dB to 2·5 dB—equivalent to an increase in transmitter power from 500 kW to 1·75 mW.

Brief details have been obtained of the basic principles upon which solid-state parametric amplifiers operate, with particular reference to the Marconi parametric amplifier/mixer, and these are as follows:

The field of research into microwave low-noise amplification is a wide one including such devices as travelling-wave tubes, tunnel diodes, masers and electron-beam or solid-state parametric amplifiers. Each of these can have many variants and this factor, together with others, such as the peculiar requirements of a specific application, overall problems of manufacture and ultimate costs, involves a systematic exploration of each which adds up to a very intensive research programme.

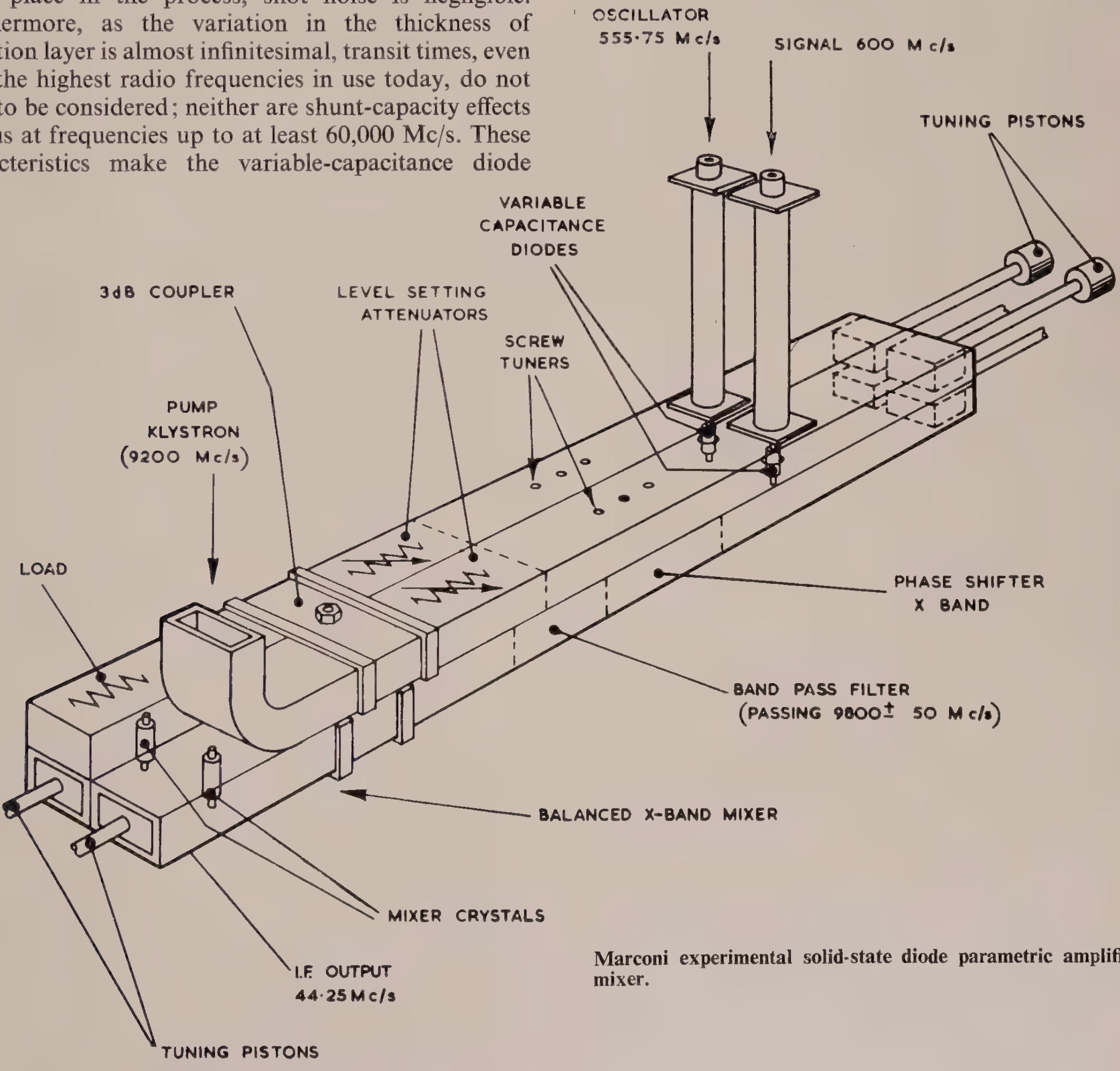
The solid-state parametric amplifier and mixer on view at Farnborough represented one of several approach aspects which are currently being investigated at the Marconi Research Laboratories. This utilizes the variable-capacitance effect in semiconductor diodes to provide low-noise amplification, but variants are again possible, notably the negative-resistance amplifier and the "up-conversion" amplifier, each of which, in turn, lends itself to different approaches. The Marconi version comes into the latter category as offering certain advantages over its contemporaries.

The basic principle underlying the operation of such an amplifier can best be understood by visualizing a resonant circuit consisting of an inductance and a capacitance connected in parallel, with an appropriate signal frequency applied across it. If, in such a circuit, the capacitance is suddenly reduced whenever the signal voltage charge on the capacitor is at a maximum and then restored whenever it is at zero, an increase in signal amplitude will result.

This additional voltage must come from somewhere and, in practice, the pumping process is carried out electrically. This is made possible, as stated earlier, by employing a silicon-diffused *p-n* junction diode. In this device, the depletion layer—the boundary between the *p* and *n* contact surfaces—is in effect a dielectric between the *p* and *n* layers, but it is a special form of dielectric in that it widens or narrows in proportion to the magnitude of any voltage which is applied across the diode. This variation results from a minute flow of electron and hole distributions, but as no actual flow of charge carriers takes place in the process, shot noise is negligible. Furthermore, as the variation in the thickness of depletion layer is almost infinitesimal, transit times, even with the highest radio frequencies in use today, do not have to be considered; neither are shunt-capacity effects serious at frequencies up to at least 60,000 Mc/s. These characteristics make the variable-capacitance diode eminently suitable for low-noise amplification of microwave signals.

Considering again the simple resonant circuit; as there are two charge cycles of the capacitor per complete sine wave it would seem to follow that the pump frequency should be double that of the incoming signal. This is theoretically the case for a maximum transfer of energy, but in practice it is difficult to maintain an exact frequency and phase relationship over long periods—under non-coherent conditions a composite output waveform is produced which, in one version of the amplifier, embodies not only the signal frequency but also a new one, namely the pump frequency minus the signal frequency. The latter is variously known as the "lower sideband", "the difference frequency", the "image" or the "idler". By the employment of a 3-port ferrite circulator, the amplified signal can be separated from the image and either or both used. In other variants both upper and lower sidebands are produced.

Another method, and the one used in the Marconi



Marconi experimental solid-state diode parametric amplifier and mixer.

amplifier, is the "up-conversion" system. In this, the pump frequency is much higher (by about 15 times) than that of the signal. The latter, in the pumping process, is "up-converted" to a frequency which is the sum of the two. This arrangement has certain advantages over the negative-resistance type of amplifier in that, when used in conjunction with a mixer of the type incorporated, the stability of the klystron pump is not nearly such an important issue, as any variations in pump frequency are cancelled at the mixer stage—in other words, should the klystron frequency wander, the mixer output still remains constant at 44·25 Mc/s.

In the Marconi amplifier, the pump source is an English Electric Valve klystron oscillating at 9,200 Mc/s. The output from this is fed along two separate sections of waveguide *via* a 3 dB directional coupler to provide equal power in both arms; each section embodies a variable attenuator and a 3-screw tuner and, towards the far end, a variable capacitance diode.

Each diode is so mounted as to protrude through to another waveguide section, mounted flat-on underneath the first so that there are, in fact, in the entire assembly four waveguide sections, two lying parallel to each other at the top of the structure, and two similar ones underneath. Into one diode is fed the 600 Mc/s signal *via* a low pass filter to isolate the external 600 Mc/s signal source from the pump frequency; the second diode is also connected through a low-pass filter to an external crystal-controlled local oscillator operating at a frequency of 555·75 Mc/s.

Considering first the signal section: Interaction between the 9,200 Mc/s pump frequency and the 600 Mc/s signal takes place, as described earlier, with a consequent transference of power from pump to signal. Along the lower waveguide section is now flowing a wide-band signal consisting of the pump frequency 9,200 Mc/s and upper and lower sidebands extending to 9,800 Mc/s (pump+signal) and 8,600 Mc/s (pump−signal) respectively. After passing through a varactor, the signal is fed through a band-pass filter centred on the sum frequency (9,800 Mc/s) and with a pass-band of ±50 Mc/s. This accepts this band of frequencies and passes them to the mixer section; it also "traps" the lower sideband which is utilized for providing a degree of regeneration.

The local oscillator section is similar except for the different frequencies involved; in this instance the local oscillator frequency is 555·75 Mc/s and the upper and lower sideband limits 9,755·75 Mc/s and 8,644·25 Mc/s. In this case also a bandpass filter in the waveguide accepts the 9,755·75 Mc/s signal.

Each of the 9,800 Mc/s and the 9,755·75 Mc/s signals passes through an arm of a 3 dB coupler to a balanced mixer stage consisting of two crystal diodes, and the resultant beat or difference signal is extracted as a 44·25 Mc/s intermediate frequency. The ends of the waveguide sections each terminate in cavity tuners. The output in the version on display is single-ended.

A comprehensive range of Pullin and Pullin-Kearfott d.c. instrument motors, servo-motors, synchros and magnetic and transistor amplifiers was shown by **R. B. Pullin & Co. Ltd.** together with examples of gear boxes and system components designed to meet customer's special requirements. Of particular interest was a new miniature size 08 d.c. motor, with an integral gearbox driving a size 08 synchro.

Formica Ltd. exhibited their range of fabric-based, glass-based, paper-based and copper-clad industrial laminates. The range is constantly being extended according to the exigencies of current developments in the radar, guided missile and other related fields. The uses of Formica printed and engraving materials were also shown with examples in the form of mimic diagrams, instrument boards and in permanent signs of all kinds.

In addition to their own standard range of precision servo components, **Vactric Control Equipment Ltd.** displayed a representative selection from the range of "Ugon" sub-miniature relays, developed by Le Prototype Mechanique of Paris and now available through Vactric. A general description of the Types 3, 5 and 7 is as follows:

The Ugon 3 relay is a sub-miniature hermetically-sealed electro-magnetic component designed to meet the Ministry of Aviation, Guided Missiles and Telecommunication requirements. Great care has been taken in the design to produce a magnetic circuit of very high efficiency. The moving armature is balanced, both as regards its mass and the magnetic moment acting during operation, thus reducing the friction forces on its axis. All these features combine to give a relay of high sensitivity with excellent resistance to vibration, shock and sustained acceleration. The relay measures 10 mm. in diameter by 25 mm. high. Four different versions are available.

The construction of the Ugon 5 relay is similar to that of the standard Ugon 3 but it has a greater resistance to vibration and shock though with lower sensitivity. With the relay energized at 70 mW it will operate under vibrations of 0 to 1,000 c/s at 80 G and withstand sinusoidal shocks of 150 G for 8 ms duration. It must, however, be pointed out that under such conditions the relay must be energized on an on-off basis. The number of operations will be necessarily more limited than that of the Ugon 3. Also the ambient temperature must not exceed 80°C.

The Ugon 7 relay is again similar in construction to the standard Ugon 3, but with modifications to give high insulation resistance. The case dimensions have been increased to 11·6 mm. diam. and 35 mm high. The make contact has been brought out at the opposite end of the case and thus its insulation resistance relative to other elements exceeds 5×10^{14} Ω. The insulation resistance between the other elements remains at 10^{10} Ω minimum. Special contacts are fitted capable of switching currents as low as 10^{-13} A. The coil temperature, however, must be limited to 50°C.

Venner Accumulators Ltd. exhibited lightweight silver-

Type PN 3550 aircraft battery.

zinc and silver-cadmium aircraft batteries in new easy-clean containers and hermetically-sealed units for guided missile applications, together with electronic and communications equipment. One example was the Type PN.3550/1 battery which provides power for operation of ancillary equipment in emergency. Also exhibited were examples of lightweight portable equipments utilizing Venner silver-zinc cells, battery chargers and automatic voltage-control units.

Alfred Imhof Ltd. had on display their standard range of cases, racks, consoles and accessories. This range is intended for housing all types of instruments and equipment in connection with missile control installations, airport installations and ground test equipment.

Also on display were the Imhofs construction systems —Imlok and Miniature Imlok. Miniature Imlok is an entirely new construction system which has been designed to suit aircraft requirements and can be used to fabricate housings for all kinds of instruments, meters, etc., for both flying and ground maintenance purposes.

A wide range of batteries for all purposes in the aircraft industry were featured on the stand of **Chloride Batteries Ltd.**

Exide batteries for civil and military aircraft were represented by a 24 V unit combining high capacity/weight ratio with long life and reliability. Exide-Ironclad batteries for use on electric trucks, light airport vehicles and tractors were also on view, together with Chloride high-performance stationary batteries which help to provide emergency lighting in airports.

Other Exide types, developed specially for the guided missile and electronics field, were prominently displayed. They combine the advantages of extremely light weight, unspillability and low open-circuit losses and are suitable for operating portable and airborne v.h.f. equipment and other special electronic devices; and for valve-operated electronic apparatus. All incorporate features having an important bearing on performance, notably the use of high-impact polystyrene for cell containers and battery covers.

A representative selection of Exide dry batteries for transistorized equipment included a leak-resistant unit cell Type T.22, capable of giving relatively high discharges for very short periods.

The **BICC Group** displayed a wide range of standard and specialized cables and accessories which emphasized the increasing application of these products in the fields of civil and military aircraft and in guided-missile development.

The latest variants of the various generic types of aircraft wiring cables on display all complied with the relevant British Standards or Ministry of Aviation specifications, and in most cases met those issued for American aircraft. Of these, an interesting product was Efglas, which is suitable for operation up to a maximum of 600 V r.m.s. and 2,400 c/s over a temperature range of −75° to +240°C. The most revolutionary feature of this cable is that the insulation consists of a matrix of glass fibres and p.t.f.e. which have been keyed together to realize all the advantageous properties of both materials for airborne use.

An interesting display on the **Bakelite Ltd.** stand illustrated the many applications this Company's products have in the electronics field. One section showed the uses of printed circuits based on copper-clad Bakelite laminated and exhibits included the applications of these materials in ground control, guided weapon and radar navigational equipment. Tools and construction jigs made from Bakelite laminated and densified wood were also featured.

Three items of some interest on the stand of **Cossor Radar and Electronics Ltd.** were:

(1) *Printed waveguides*

The basis of the printed waveguide is a planar or flat strip. The strip is photo-etched on a supporting dielectric and functions as a conducting guide for the propogation of electromagnetic waves. By variation of the strip pattern the structure may be adapted to the fabrication of all forms of microwave elements; the more complex the microwave system, the greater the benefits of strip transmission. The technique simplifies waveguide plumbing to the printed circuit, and eliminates the high cost of machining conventional waveguide and co-axial systems. Since all models of any one system are reproduced by a photographic process, the accuracy of repetition of mechanical dimensions is very high.

(2) *Quartz delay lines*

Cossor quartz delay lines are ultrasonic devices for the storage of pulse information over periods of 3 to 2,500 μs, wherever maintenance of pulse amplitude and shape is important. Delay lines of this type consist of an irregular polygon of fused quartz with piezo-electric transducers bonded to two facets on opposite sides of its axis of symmetry. When the transmitter crystal is excited electrically, an ultrasonic signal is emitted into the quartz and reflected internally a number of times before emerging at the receiver. The number of reflections, and thus the path length, can be controlled by varying the shape of the quartz plate, which is cut for an optimum ratio of path length to volume of material. The slow propogation rate of the acoustic medium and the multiple internal reflections of the transmitted beam make possible very compact and lightweight units which are versatile elements in systems requiring dynamic storage of pulse data. The units may be mounted in any position, and variation of delay with temperature change is of the order of 70 parts per million per degree centigrade.

(3) *Magnetostrictive delay lines*

Cossor magnetostriction delay lines permit dynamic storage of pulse information for periods of 1·5 μs to 2·0 ms. These lines consist basically of a nickel tube, the ends of which are terminated in matched p.v.c. leads. Transducers in the form of encapsulated ferrite cored coils are threaded onto the nickel tube. When an input pulse is applied to the input transducer a magnetic field pulse is produced along the axis of the nickel tube, which in turn promotes a strain pulse. This is then propogated in both directions along the tube at a velocity equal to the speed of sound in nickel. As this strain pulse passes through the pick off coil, an output pulse is generated. By varying the distance between the input and output transducers, adjustment of delay time can be made in circuit, without disturbing the unit. The complete delay lines are mounted in metal containers.

The chief items of interest on the **Belling & Lee Ltd.** stand were the further developments of the "Camlecon" and "Collecon" connectors which were introduced at last year's Show. They were developed primarily for the aircraft and guided missile industry, to overcome the shortcomings of conventional plugs and sockets when subjected to extremely high forces of acceleration, vibration, and shock. Since each socket is individually adjusted to its mating pin by a very large increment of contact pressure *after engagement*, random variations under the severest working conditions have been eliminated, yet insertion and withdrawal forces, and consequently wear, are restricted to better than normal proportions. At the same time, where the effects of variations in climatic conditions must be excluded, sealing is incorporated. The fundamental principle underlying these connectors produces such an outstanding improvement in performance that it has been extended into other types of connectors in which an exceptionally high standard of reliability is required; examples were shown for general duties in all Services.

In addition, there were the new "Belling-Lee" Filtron interference suppressors, hermetically-sealed and suitable for operation in the temperature range −55°C to +85°C (some types up to +125°C). They cover ratings from 0·15 A to 300 A, and up to 18,000 V d.c. working with a maximum attenuation exceeding 100 dB over a frequency range from 14 kc/s to 10,000 Mc/s.

Other new components introduced since the last Exhibition included additions to the series of miniature and sub-miniature coaxial connectors, fuselinks for semiconductor rectifier protection, an improved range of miniature wander plugs and sockets, a new general-purpose terminal of moderate price, flexible terminal blocks, and a variety of items for printed-circuit applications.

Westinghouse Brake and Signal Co. Ltd. demonstrated two applications of Trinistor silicon-controlled rectifiers on their stand. One was a power inverter producing an output at 400 c/s with a truly sinusoidal waveform; the other a compact a.c. power regulator rated at 13 kVA incorporating a fan for forced-air-cooling.

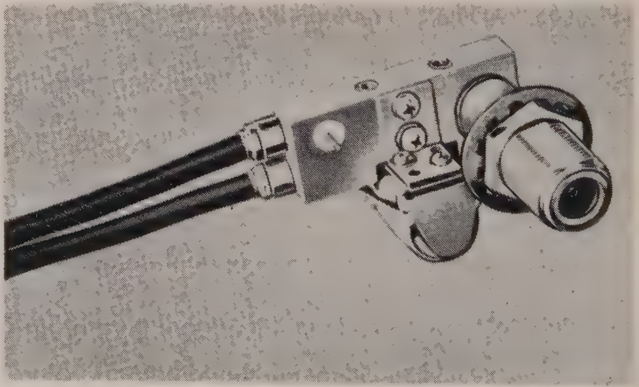
Among other semiconductor devices exhibited were a full range of silicon diodes rated from 750 mA to 175 A with peak reverse voltages of 100 to 1,200 or 1,800 V. Currently available Trinistor silicon-controlled rectifiers rated at 16 A and 26 A at 400 V peak were also featured, together with smaller and larger types to be produced shortly.

The new Westinghouse H series of crystal-aligned rectifiers utilizes aluminium-based selenium elements manufactured by an automatic and closely controlled vacuum deposition process. The new process elements, which embody a crystal-aligned selenium layer and an improved back contact, have characteristics which result in a greatly improved service life expectancy together with higher permissible current densities.

Other selenium-type rectifiers displayed included lightweight high-temperature units to DEF.5243 capable of operating in ambient temperatures of up to 85°C, and miniature and tubular rectifiers in various types of assemblies.

The Plessey Co. Ltd. included in their wide range of exhibits a representative selection of connectors, including the UK-AN, the type-approved Mark 5 (adopted by the Ministry of Aviation as the Pattern 104 connector) and the recently introduced Mark 6, which provides for twice the contact complement of either the Mark 5 or UK-AN ranges in an equivalent shell size.

A typical selection of type-approved and other electronic components, specially developed for applications in airborne and associated ground equipment, was also exhibited.



Plessey Type CX coaxial relay.

A very wide range of equipment and components was shown by **Elliott Brothers (London) Ltd.** The components included the following items:

(1) The Bristol miniature syncroverter switch, which

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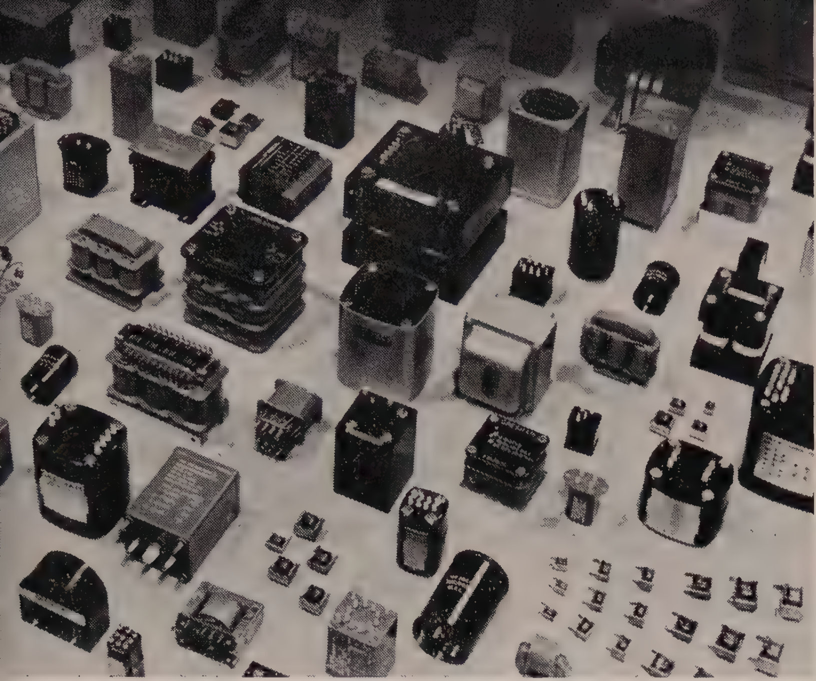

Some of the many types of small transformers now being used by the Electronics Industry.

A SURVEY OF TRANSFORMERS IN THE ELECTRONICS INDUSTRY

Part 2. Environment

By D. R. Adams
Gresham Transformers Ltd.

There is now generally available a wide range of transformers covering the needs of most users and further types are being developed continuously by the industry for more specialized application. It is the purpose of this article to review the more popular of the designs available and to comment on their suitability for various applications.

The article is divided into three parts as follows:

Part 1. *General classification:* **Here the various types are considered broadly and comments are made on the factors that must be taken into account before a choice is made for a specific application.**

Part 2. *Environment:* **This deals mainly with the wide variations of environmental conditions encountered in service and the methods used by manufacturers to provide a product having adequate life and reliable performance.**

Part 3. *Materials:* **The more popular materials in use will be briefly discussed and comments are made on the reasons for their choice. A list of some of the many governing specifications involved is included.**

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AT THE present time, a transformer can be used on the ground, on/under the sea, or in the air. They are, of course, being used in outer space as well, but, for the time being, this application is highly experimental and will be disregarded.

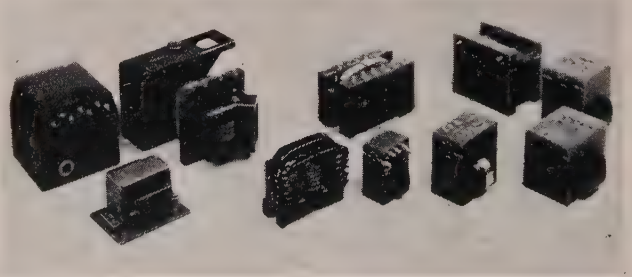
A transformer can be affected by its environment in many ways, not all of them bad, and the various factors involved should be specified as completely as possible at the time of ordering. This will enable the designer to take advantage of any factor which will assist him to reduce the size, weight or cost, and to take into account all those other factors for which protection must be provided.

It would be as well to point out at this stage the unfortunate and wide-spread practice of asking the transformer designer to meet specifications that are unnecessarily severe. The main Government specifications which apply to transformers are RCS.214, RCS.11, and D.E.F.5214 and these documents do not take into account any special conditions which may exist in the equipment. For example, blown air or other means may be used to cool the main equipment and could cool the transformer. If this fact were known in good time it may well be possible to supply a smaller and lighter component, which would avoid the possibility of selecting a transformer in a temperature category which assumes the air is still. That such specification errors occur is often due to the fact that these specifications require a temperature test to be carried out on a test bench in still air and it is difficult to obtain Type Approval for the transformer in the equipment.

An unnecessarily high humidity class is often specified, presumably on the assumption that it is better to play safe and have the best. A case comes to mind of an H.1 transformer being specified for use on a battery charger for use in this country, where neither the voltage nor the operating conditions would justify such a high-grade component.

The other two main offending clauses are flash test (voltage proof) and insulation resistance. A 2,400 V peak test is often specified for miniature transformers working at very low voltages, for example in transistor circuits, and much time and effort is expended in complying with

Various transformers cast in epoxy resin designed to take advantage of cooling available in the main equipment; the two at top left by pumped oil and the remainder by mounting the cores on a heat sink in contact with the main chassis. (Gresham Transformers Ltd.)

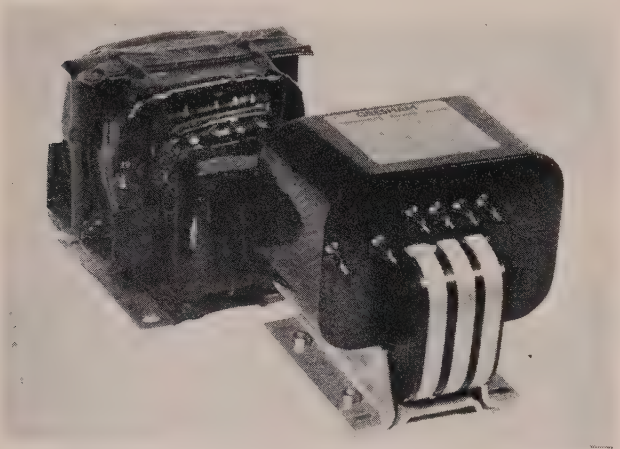


this quite unnecessary requirement. Further, insulation resistances of greater than 5,000 MΩ are required in order to obtain Type Approval for some small low-voltage transformers where, in the opinion of the writer, a few megohms would be quite satisfactory.

The following list giving most of the environmental factors to be taken into account by the manufacturers, together with some others which, although not strictly part of the environment, nevertheless influence the design.

1. *Ambient temperature*

This is a most important factor and will influence the size, weight, and the materials used in the construction of a transformer. It can vary from −65°C (mainly under storage conditions) up to 100°C or even higher. If very wide changes in ambient temperature occur while the transformer is being used it can also influence the regulation and, hence, the output voltage. This effect, however, is usually small and can generally be ignored.



A high-voltage, resin-cast transformer, designed to be interchangeable with and replace an existing American design shown in the background. It was designed to withstand ambient temperatures from −40°C to +85°C and mechanical shock up to 40 G. All the other tests specified in RCS.214 H.1 were also met. (Gresham Transformers Ltd.)

2. *Very low temperatures*

These can cause embrittlement of some insulating materials; for example sleeving, and, if combined with severe mechanical shock or vibration, cracking with subsequent electrical failure could occur. Therefore, it is necessary to use only materials that are satisfactory at these temperatures.

This was a particularly difficult condition to provide for on resin cast transformers in the early days. Fortunately, with improved resins and manufacturing techques, this difficulty has been largely overcome.

3. *High temperatures*

Here again, it is nearly always the insulation that is the limiting factor. High temperature will degrade unsuitable materials and this usually results in a lowering of the insulation resistance and even failure if the voltage is high enough.

BSS.2757 lays down safe upper temperature limits for most popular materials and a list of these is to be given in Part 3 of this article. It is a simple matter to add the temperature rise of the winding to the ambient temperature to obtain the maximum winding temperature and then select a suitable material from the list. Care must be taken, of course, to use a varnish of the same temperature category, for impregnation.

4. *Humidity*

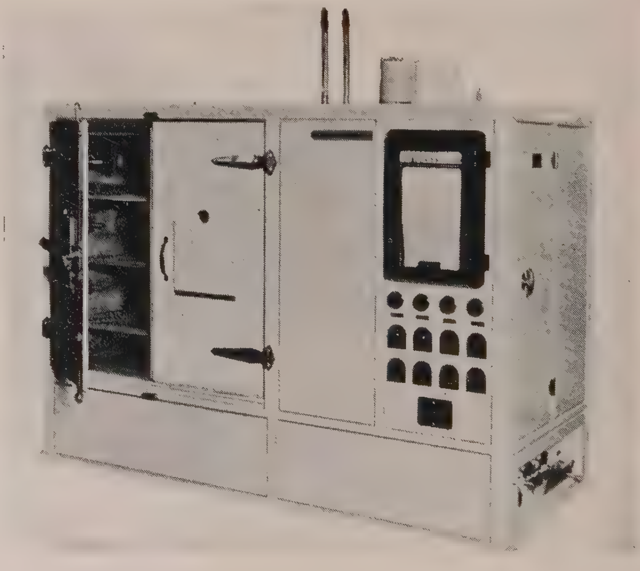
Transformers can suffer, if they are not properly protected, from both extremes of humidity. For example, extremely dry conditions could, in rare cases, cause embrittlement of certain types of sleeving and other insulating materials. It is, however, conditions of high humidity which cause the most trouble and the danger of excessive dampness inside a coil working at even reasonable voltages is too well known to be discussed. It is worth noting, in passing, that high voltage, in conjunction with moisture, can produce corrosion in certain materials.

Protecting a transformer against the ingress of moisture has occupied a good deal of the attention of designers in the past, and still does today. Three main methods are in use.

1. *Open type transformers*
   - (*a*) Wax or bitumen dipping can be used where the conditions are not too severe.
   - (*b*) Varnish, usually solventless, impregnation of the coil, followed by one or more dip coats of a dipping varnish to provide a tough skin through which water vapour will penetrate only with difficulty.
2. *Hermetically sealed transformers*

As described in Part 1 of this article (***Radio & Electronic Components***, July 1961), the transformer is sealed

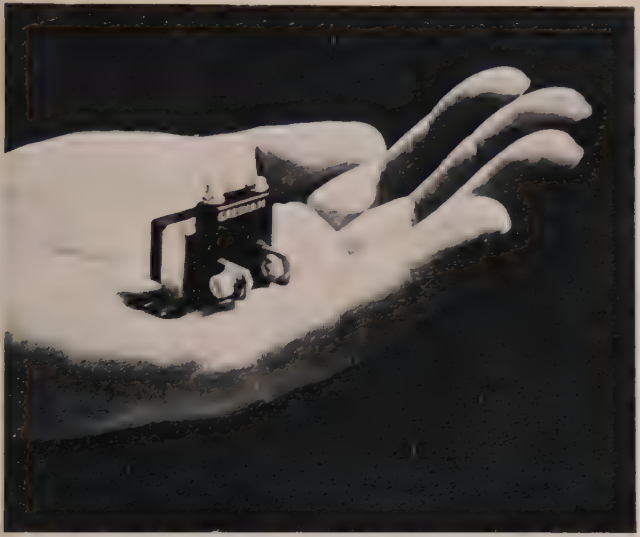
A humidity cabinet fitted with recording instruments for checking that components are proof against the ingress of moisture. The humidity is controlled by contact making wet and dry bulb thermometers seen projecting from the top. (Barlow Witney).



in a case, usually of tinplate, and the seams are soldered. The terminals consist of ceramic or glass seals, also soldered into the case. The unit may be filled with air or various liquids, of which oil is by far the most popular, and, provided the can does not leak, water cannot get in and extremely good protection results.

3. *Resin casting*

This construction, already described in Part 1, provides extremely good protection and, for light weight, small size applications, is the best of all, saving as it does the weight of the container and oil. For example, in a recent airborne application, a resin cast microphone transformer weighing 1¼ oz. replaced a conventional oil-filled hermetically-sealed "C" core transformer weighing 4½ oz. Both transformers passed the H.1 humidity tests laid down in RCS.214.



A 40 A current transformer operating at approximately 2 kc/s, weighing 1¾ oz, designed to withstand the extreme vibration encountered in the wings of an aircraft.

The effectiveness of the protection is usually checked by carrying out tests in a "humidity cabinet" where the conditions are carefully controlled in accordance with the relevant specifications. Barlow-Whitney cabinets, similar to the type illustrated, are used extensively for this purpose. This particular model, fitted as it is with recording gear, enables a permanent record of the conditions inside the cabinet to be kept, even when the equipment is unattended.

The insulation resistance between windings and between windings and earth is measured before and after conditioning, and the difference between the two sets of figures is a measure of the quality of protection. Samples from normal production are regularly taken and tested to ensure that the processing is being correctly applied.

5. *Sunlight*

It is mainly the ultra-violet content of sunlight which is damaging and, as transformers are usually enclosed in some electronic equipment and thus protected, this is not often important. It should be noted, however, that the surface of some epoxy resins can be damaged by prolonged exposure to ultra-violet light, but the writer has no knowledge of any failures that have resulted from this cause.

6. *Dust and dirt*

Dust is not a very important factor to the designer of transformers for the electronics industry provided that it is inert—most normal types will put up with almost unlimited amounts. If, however, it is in combination with damp, it may bridge across terminations and form conducting paths resulting in breakdown. It could also cause corrosion of some of the metal parts as anyone will know who can remember brass or copper electrical fittings being used in a poorly ventilated kitchen.

The use of stainless steel or suitable plating may be the answer but it is better to consult the manufacturer if the atmosphere is likely to be seriously contaminated.

The designer of the main equipment usually takes care to see that adequate protection is provided against the ingress of excessive dust but, if this is impossible, the problem can be overcome by using the resin-cast or hermetically-sealed type of transformer with stand-off terminations longer than would normally be required, so that dust and dirt can form on the horizontal surfaces without damage. It is also possible that a simple cover over the terminals may be all that is required.

7. *Salt spray*

The problem of salt spray is, of course, mainly found on ship board installations where, although equipment may be inside the cabins, fine particles of salt can, nevertheless, find their way inside. Coupled with high humidity conditions, this could result in highly corrosive salt water being drawn into the coil by changes of temperature and damage may result if it is not suitably protected. Fortunately, the protection against humidity is usually sufficient to protect also against salt spray.

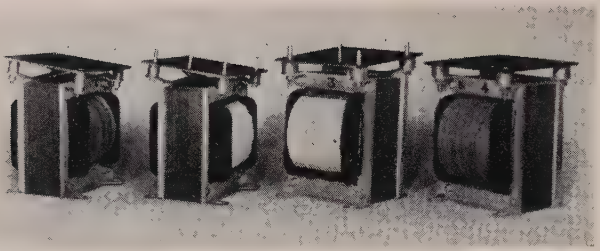
It may be as well to mention other chemical contaminants such as acid fumes. This is not normally allowed for on commercial equipment but protection can be provided in some cases.

8. *Vibration*

Vibration can be encountered almost anywhere where equipment is used near rotating machinery. This applies mainly to ships, and particularly in the wings of aircraft. Generally speaking, provided the lead-out wires are properly anchored and the transformer is properly finished, this is not a serious problem to the transformer designer, but is often so to the designer of equipment where some valves and relays can be particularly troublesome.

9. *Mechanical shock*

This is very important on board fighting ships where equipment may be fixed to the deck and very severe shocks can be transmitted, particularly when the guns are firing or when depth charges are being exploded near the ship. Various specifications cover this aspect and a number of classifications of shock are available from



Four dummy open-type transformers illustrating the effect of heavy mechanical shock on a frame assembly too light for the duty. The transformers were mounted from the terminal board end and subjected to 4,000 blows of approximately 40 G.

10—200 G. These are usually the subject of agreement between the user and the transformer maker and the mechanical design must be carefully carried out if these conditions are to be withstood.

Tests to ensure compliance with this condition are carried out by mounting the transformer on a heavy steel base, which is then subjected to a number of blows of the required magnitude. The illustration shows what happens during this test when frames of inadequate strength are used. Once again, the weight and size of the transformer should be kept to a minimum to reduce the effect of these tests and full use should be made of any cooling available in the equipment to enable this to be done.

10. Air pressure

The most important aspect of air pressure is met in high-flying aircraft where, due to the low pressure of the air, large clearances must be allowed between terminations for even comparatively low voltages. As has been mentioned before, this can be overcome by pressurizing aircraft cabins or the equipment but, if this is impossible, a useful way around the problem for high voltage work is to resin cast the transformer and to bring the terminals out in insulated cables so that no bare terminations are subjected to this low pressure condition.

Low pressure on oil-filled hermetically-sealed transformers can also have the effect of increasing the stresses in the can by comparatively increasing the internal pressure. This is more important when the transformer is running hot, as it will tend to do at high altitudes (due to lack of cooling air). On the Type Approved "C" core component to RCL.215, the safety factors are sufficient to take care of this, but this fact should be kept in mind when designing non-standard cases, particularly if they are of rectangular shape.

Sometimes transformers are required for use inside pressure vessels, operating at many atmospheres and, under these conditions, oil-filled hermetically-sealed "C" core types may be unsuitable, due to the danger of the case collapsing. In this circumstance, resin cast units are probably the most suitable.

11. Mould growth

This has been a serious problem in the past as many organic materials are attacked in this way. Fortunately, considerable research has been carried out and most of the approved materials used today are either impervious or are treated to make them so.

12. Magnetic field

This can be a disadvantage in two ways:

(*a*) By the stray field from the transformer interfering with surrounding equipment; for example, on an oscilloscope where the field can affect the deflection of the beam.

(*b*) By stray field from external sources causing parasitic voltages to be induced in the transformer; for example, microphone transformers can be influenced by the field of mains transformers, if close enough, and "mains hum" may result.

The remedy for both these affects is magnetic screening, usually by mounting the transformer in a can which may be of mild steel or mumetal depending on the degree of attenuation required. Several mumetal cans, one inside the other, with copper cans between, can be used in extreme cases, and this arrangement is even used with an astatically-wound transformer to reduce the effect still further.

This type of transformer has two coils mounted side by side on separate limbs which tend to cancel out the effect of stray field linking the coil.

13. Fire risk

If protected by fuses, transformers do not usually represent a serious fire risk but, in some cases, even a small risk is unacceptable. The methods of reducing this still further are as follows:

(*a*) *Open and shrouded types*

Thermal cut-outs of the bimetal type may be clamped to the coil or fusible links incorporating low melting point alloy joints may be used. In either case, it is important to ensure that these are in good thermal contact with the coil.

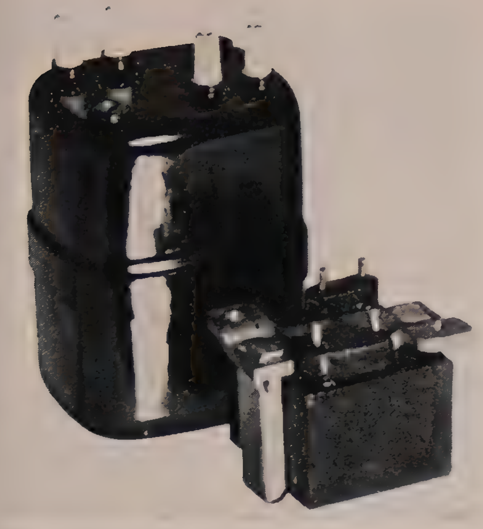
The former method is used on the amenity socket transformer illustrated in Part 1 of this article, and has the advantage of an additional heater which compensates for the difference in temperature between the inside of the coil and the cut-out. This provides extremely rapid protection in the case of severe overload. These cut-outs can be supplied either for resetting by hand or automatically when the coil temperature has fallen to a safe value.

(*b*) *Oil filled units*

This type is the worst of all from this point of view and, under severe overload or short circuit conditions, the internal temperature and pressure can rise high enough to burst the case when very hot and inflammable oil will be ejected. They may be protected by either of the cut-outs mentioned above. A further safeguard would be the filling of the unit with silicone oil or with one of the several non-inflammable cooling media available.

(*c*) *Resin cast units*

These are the best of all the common types and are extremely difficult to ignite. However, if some



A pair of transformers showing the reduction in weight and size achieved by resin casting the coil of a small audio-frequency transformer. The weight was 1½ oz. of the hermetically-sealed type with which it was interchangeable mechanically and electrically. (Gresham Transformers Ltd.)

epoxy resins are held in a flame for long periods, they will burn with difficulty and this burning is inhibited by the normal loading with inert fillers. They can be reduced to a condition where they are self-extinguishing by special additions to the mix. The usual result of severe overload or even short circuit on these transformers, if continued long enough, is a puff of smoke and a cracked casting. The winding usually goes "open circuit" and no further damage results.

14. Ionization

Ionization is a most important aspect of high-voltage transformers and, if not controlled, can and has caused breakdown in service of units that have passed all their tests including a high-voltage test of more than twice the working voltage.

On the other hand, provided that the discharge is occuring at a point that is adequately ventilated, or on a suitable material; e.g., porcelain; it can be considerable without seriously shortening the life of the component.

The subject of ionization is a specialized study and much work has been done on the subject; notably by Garton and Mason at the Electrical Research Association. Ionization detection equipment is available and testing is now routine with many manufacturers.

An interesting example comes to mind of a high-voltage filament transformer which was causing interference with a high gain r.f. amplifier close by, due to ionization at the terminals. This was overcome by designing a special resin-cast filament transformer which was ionization free up to 45 kV peak.

15. Conclusion

There are, of course, other and less common aspects of the environment affecting the design of transformers that have been disregarded. The main points are those mentioned above.

In conclusion, the need for close co-operation between the designer of the main equipment and the transformer manufacturer should be emphasized.

1. Give the designer all the relevant data on working conditions as well as the electrical specifications.
2. Don't call up unnecessarily severe tests.
3. Don't call up unnecessarily tight tolerances.
4. Call in your manufacturers at the earliest moment to discuss construction and electrical design.

This will result in a reliable job at the lowest price.

To be concluded.

FARNBOROUGH AIR SHOW 1961

Continued from p. 754

is a polarized single-pole, double-throw, non-resonant chopper which provides break-before-make action synchronized with the current wave of the driving source. It converts low-power d.c. signals into alternating voltages which can be amplified and applied to electronic, electrical and servo systems. It can also be used as a precision synchronous rectifier.

(2) The Clare Type F relay, which was designed to fill the needs of military and industrial applications which demand reliability under extremes of temperature, heavy shock and severe vibration.

(3) The Elliott range of control transmitters and transformers in Bu-Ord and M of A standard frames which now includes a miniature size 08 synchro and an electrical two-speed synchro. Another important item is the Elliott Size 11 stub synchro, with a standard performance and front-housing, but a shorter frame which gives a 43% space saving. It is designed to operate from a 26 V 400 c/s supply.

(4) Elliott torquemotors, which are widely used throughout the aviation industry. All units are now available with angular displacement or velocity a.c. pick-offs for feedback or control purposes. Type 130, which was introduced recently, has been specially designed to give systems engineers the widest possible choice of performance characteristics.

(5) Examples of precision-built miniature a.c. and d.c. electric motors on show included the new size 08 and size 10, 11 and 18 two-phase a.c. servomotors (designed to Bu-Ord and Ministry of Aviation specifications) operating from 50/60 and 400 c/s supplies.

(6) The size 11 permanent magnet 28 V d.c. motors exhibited are covered by Royal Aircraft Establishment "type approval" certificates. A size 08 permanent magnet d.c. motor, which is under development, was also on show.

APPLICATIONS OF SILICON *p-n* JUNCTION CAPACITORS

By J. G. Scott

Hughes International (U.K.) Ltd.[*]

Hughes silicon capacitors are p-n junctions formed in single-crystal silicon by techniques used in the manufacture of semiconductor devices. They are hermetically sealed in a single-piece fused-glass package. This article gives a short description of the device and discusses some of the applications.

Introduction

SILICON CAPACITORS are new devices with properties unlike similar components. Because of these unique properties they make possible many functions which were previously impossible. It is imperative, therefore, that they be regarded as new devices, and that their applications be approached with an open mind in order to derive the greatest possible return from an imaginative and ingenious approach to new, desirable equipment not yet existing.

At a *p-n* junction the density of charge carriers (electrons in the *n* region and holes in the *p* region) is reduced virtually to zero when a voltage is applied across the junction in the reverse direction from that causing easy current flow. As the voltage increases, the region of zero carrier density, known as the depletion region, gets wider. In effect, this moves apart the two conducting areas and decreases the capacity as if there were two metal plates separated by a dielectric whose thickness was variable. The area of the plates remains the same; the dielectric constant is unchanged; but the thickness of the dielectric varies according to the applied voltage.

In the normal bias direction, the capacity will continue to decrease as the voltage is raised up to the limits given in the specifications. A further voltage increase can effect permanent damage to the capacitor if the supply has fairly good regulation. Usually, however, the biasing voltage is applied through relatively high resistance values. Hence, adequate protection from abnormal voltages is afforded by the current limiting properties of the isolating resistors.

Leakage current experienced with the silicon capacitor is the reverse leakage current of the junction operating as a diode with a reverse voltage applied. With silicon, leakage currents are extremely small (a few milli-microamperes), causing this device to act like a perfect capacitor with a very high shunting resistance. Since, in addition, the series resistance is very low, *Q* will be high enough to fulfil the requirements of nearly all capacitor applications.

Physical Configuration

The capacitors are packaged in a fusion-sealed glass envelope which is impervious to moisture, fumes, and other external contaminating agents. This package, developed many years ago at Hughes, is still unsurpassed in effectiveness. Not only does it protect the internal elements from contamination, but it contributes substantially to the physical ruggedness and electrical stability of each capacitor. They are particularly suited for printed-circuit use and can be inserted easily by automatic assembly machines. Furthermore, their small size minimizes storage and installation problems. These features are in direct contrast to those of the larger and more unwieldy air capacitor.

Electrical Characteristics

At the moment, there are seven standard types of silicon capacitors in the Hughes range, each with its own characteristics and individual advantages. In every instance, the *Q*'s are unusually high and the range over which the capacity can be varied is large.

Nominal capacitance ranges from 35 to 100 pF at −4V and the variation in capacitance with voltage and temperature is given over the operating temperature range by—

$$C = \frac{2{\cdot}12K}{(V + 0{\cdot}71 - 0{\cdot}0022T)^{0{\cdot}49}}$$

where K=capacitance at −4V and 25°C
V=applied reverse bias
T=temperature in degrees Centigrade.

The *Q* is inversely proportional to frequency, and typically the *Q* varies from 175 to 360 at 5 Mc, depending on the type capacitor. The *Q* increases with applied bias, but bias has a decreasing effect as the frequency is increased.

Applications

Use in tuned circuits. The effect of these particular silicon capacitors upon tuned-circuit design is likely to be considerable, for these tiny, light-weight devices possess remote and automatic control possibilities which are revolutionary. For the first time, radios can be

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[*] Glenrothes, Fife, Scotland.

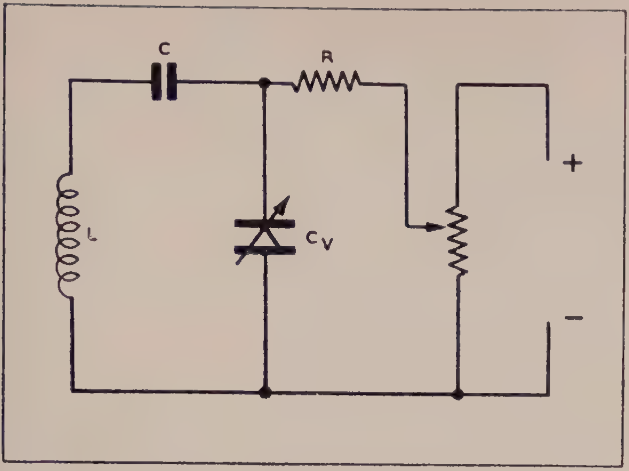


Fig. 1. Single tuned-circuit.

tuned electrically at the end of a long wire rather than mechanically with a rigid shaft. Immediately, this fact suggests a single radio installation built in to a house and controlled from several locations. Car radios, too, can be more conveniently placed, and operated by multiple controls.

Equally significant, these capacitors make "signal seeking" possible in tuned circuits. Instead of varying a potentiometer, one merely pushes a button and the capacitors sweep up the band to the next station and "lock-on". Another push on the next station is precisely tuned.

Once again, the advantages are apparent. Non-mechanical pushbutton tuning is ideal for pocket radios, home installations, and car radios.

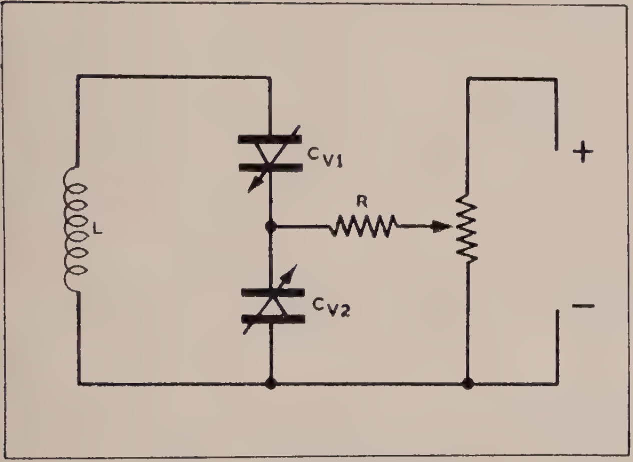


Fig. 2. Alternative circuit to Fig. 1.

These "signal seeking" circuits also have inherent automatic frequency control characteristics. Not only will the receiver lock on the station but it will automatically follow the station whenever the transmitted frequency varies. This feature is particularly advantageous in military or civilian communications and telemetering systems.

Manual tuning. Fig. 1 illustrates a single tuned-circuit with L and C_V comprising the basic components. C is a blocking capacitor, while R isolates the signal from the bias circuit. R can have a value as high as several Megohms.

The advantage of this circuit is its simplicity. However, it has two drawbacks. The signal voltage can create across the capacitor a self-bias which depends on the amplitude of the signal and which may reduce the capacity range considerably. Secondly, this self bias causes distortion if the signal amplitude is modulated.

Both of these objections can be overcome by utilizing the circuit in Fig. 2. Since C_{V1} and C_{V2} are connected in series-opposition, no self biasing due to the signal can occur. With this circuit, the bias can be reduced to 0 and can even be reversed to a positive value of up to 0·4 V. Thus, large capacity changes can be obtained and distortion avoided.

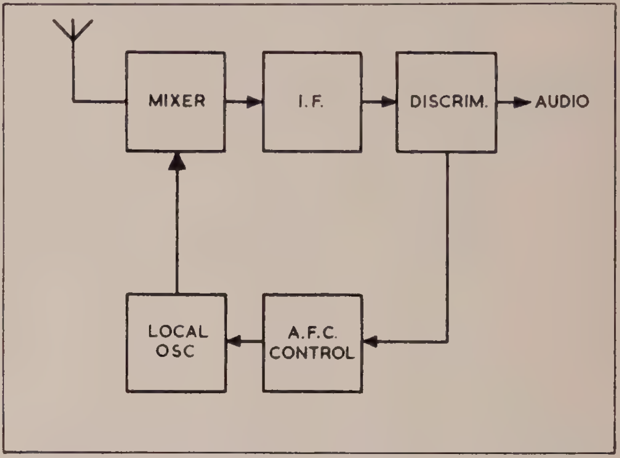


Fig. 3. Overall system for automatic frequency control.

Automatic frequency control. In automatic frequency control, the silicon capacitor replaces a reactance valve. The output voltage from the discriminator varies the voltage on the silicon capacitor and hence the local oscillator frequency so as to correct for any frequency drift due to extraneous causes. Fig. 3 illustrates the overall system. If voltage tuning is used in the receiver, the discriminator output can be fed back directly to the tuning capacitors, and a.f.c. accomplished at virtually no additional cost.

Tracking of tuned circuits. Because the silicon capacitors have very consistent C_{versus} V function exponents (*C-V* curves are parallel), almost perfect tracking of tuned circuits may be obtained by:

(i) matched silicon capacitors
(ii) several units in parallel and/or series so that the combinations match
(iii) slug-tuned inductors
(iv) padder or trimmer capacitors
(v) adjustable voltage dividers to shift the voltage range and thus match the capacitance range.

However, when an oscillator circuit must track r.f. circuits in a superheterodyne receiver, another problem arises; the frequency of the oscillator circuit differs from the frequency of the r.f. stages by the i.f. frequency. As a

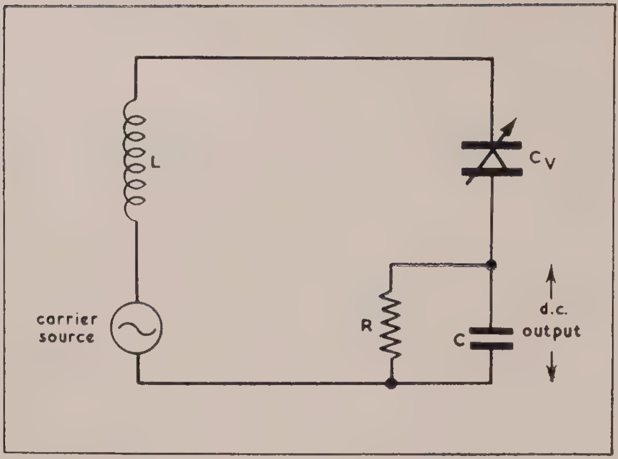


Fig. 4. Carrier-energized bistable circuit.

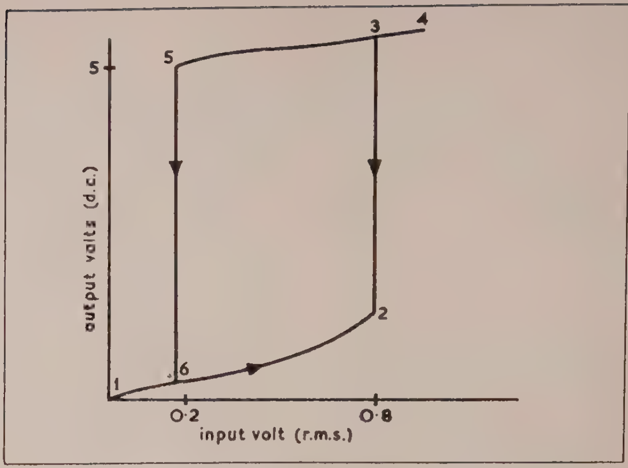


Fig. 5. Relationship between output volts d.c. and input volts r.m.s.

result, silicon capacitors in the r.f. circuits must be tuned not only over a different range, but also through a different ratio of capacities and voltages compared with the capacitors in the oscillator circuit. This can be accomplished by using ganged potentiometers with the correct relative value and taper, or by using a voltage divider network to control the range of voltage variation and operating portions of the *C-V* curves for each capacitor.

Other applications. Fig. 4 illustrates a carrier-energized bistable circuit which consists of a high frequency source driving a series combination of *L* and C_V. This circuit utilizes both the variable capacitance and the non-linear conductance characteristics of the silicon capacitors.

The effective capacitance of the non-linear device depends upon the amplitude of the d.c. and a.c. components across it. Due to diode rectification, the d.c. voltage is essentially equal to the peak a.c. voltage applied to the capacitor. This voltage depends on the frequency and amplitude of the voltage source and the circuit component.

The circuit may be tuned through series resonance by varying the amplitude or frequency of the source. If the circuit *Q* exceeds a minimum value the change in output voltage will be abrupt. Fig. 5 shows the relationship between output volts d.c. and input volts r.m.s.

With an energizing carrier of $\frac{1}{2}$ V r.m.s., a d.c. output voltage change of several volts is obtained. The switching time with a carrier of 2 Mc/s is 2 μs. Triggering can be accomplished by momentarily changing the input voltage beyond the critical amplitudes (points 2 and 5 in Fig. 5) or by altering the frequency.

The silicon capacitor can also be used to vary the pulse width in free-running and monostable multivibrators and blocking oscillators.

Other applications include r.c. oscillators, phase and frequency modulators, electronically controlled filters, frequency multiplication, function generators and many radar applications.

NEW COMPONENTS ANNUAL

British Miniature Electronic Components and Assemblies Data Annual 1961-1962

By G. W. A. Dummer & J. M. Robertson
479 pp. Pergamon Press Ltd. Price 80s.

THE editors of this *Annual* have made a comprehensive collection of data obtained from British manufacturers of miniature electronic components. A good selection of high-quality components is included, and many minor parts are listed, e.g. hermetic glass-to-metal seals and cable clips. Details of the construction of a number of components are given, and the numerous diagrams are, almost without exception, large, clear, and adequately dimensioned. Details of services provided by some firms are given and include chemical milling of fine metal parts, and the production of various types of printed circuits.

The book will be very valuable to designers of miniature equipments. It is a pity that the editors decided to omit all information about transistors, on the grounds that "other publications are available". The inclusion of some information about high-quality transistors, around which much miniature equipment is designed, would be welcomed. Data on miniature batteries have also been omitted, but are being considered for future issues.

As the information is arranged alphabetically there is fortunately little need to refer to the index which may be found at the front of the book, after 18 pages of advertisements. The only departure from a logical arrangement of the contents is a division of insulated connecting wire, etc. into "cables" and "wires".

A. G. DAY

Vacuum Forming of Plastics

Its Application to the Radio and Electronics Field

By R. W. Harwood, F.R.S.A.

Director, Omega Plastics Ltd.

A brief outline is given of the current methods used for the vacuum forming of plastics. Mould design and the various plastic materials in common use are discussed, together with a survey of the various applications which this process has in the radio and electronics field.

VACUUM FORMING is a method of producing shaped mouldings from plastic sheet. Such plastic materials are thermoplastic, which means that when they are heated above distortion temperatures they develop an extended linear molecular construction causing them to become rubbery in nature. In this condition they can be formed to shape by air pressure, suction, or pressure by male and/or female tools. After forming, when the sheet is cool, the internal molecular construction partially interlocks forming a rigid or semi-rigid component, according to the material, which retains its shape until again heated beyond its distortion temperature, when it eventually reverts to the flat sheet at suitably high temperatures.

Methods of Forming

It is generally understood that vacuum forming basically consists of heating a thermoplastic sheet held in a clamped frame and, by the introduction of suction beneath the sheet, the resultant atmospheric air pressure above causes the sheet to collapse on or into the mould, thus forming the required article.

Today, the process makes use of a number of variations to suit the complexity of the component to be produced.

There are six main methods of forming, namely, negative vacuum forming, drape forming, plug forming, vacuum snap-back forming, bubble forming and air-pressure forming.

Negative vacuum forming. This method is used for simple mouldings such as trays up to 4 in. depth (provided the minimum width is at least twice the depth) or for low relief mouldings where fine detail or embossing is required on the surface that contacts the mould. The plastic sheet is gripped between two clamped frames which are supported above the female mould, thus creating an airtight seal between the frame and the mould. When the sheet has been heated to the correct temperature, the air beneath the sheet is withdrawn by the use of a vacuum pump, and the atmospheric air pressure above the sheet causes it to collapse into the female mould forming the product. To release the moulding when cool, air pressure is applied beneath it to free it from the mould and the clamp frame is opened to enable its removal.

Drape forming. This method allows deeper draws and gives thicker wall sections where a male mould is used and pushed upwards into the heated sheet, or the frame holding the sheet is moved downwards onto a fixed mould. Evacuation of the air beneath the sheet takes place when the frame has formed a seal with the mould base. The quality of the moulding is controlled by the temperature of the mould, speed of draping and rate of air evacuation.

Plug assist forming. Where the inevitable thinning of the sheet is not required, either at the base or top of a moulding, it is possible by the following three methods to restrict it to the centre portions of the side walls, and to distribute the material more evenly over the area of the moulding than by the previous methods.

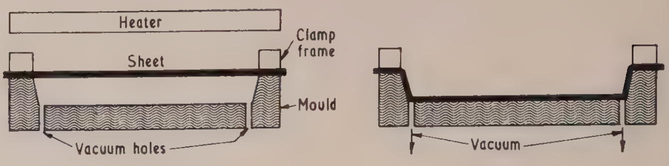
In plug assist forming, a heated top former is forced into the heated sheet which is clamped over the female mould. When the plug has almost reached its lowest limit, the vacuum is applied. Rapid descent of the heated plug is essential, and it may be found necessary to use a slip ring for clamping, allowing the heated sheet to slip inwards as the plug descends thus allowing more material for stretch on the side walls.

Vacuum snap-back forming. Here, as in the aforementioned method, a plug is used, but the heated sheet is sucked into the female mould before entry of the plug, and once the plug is fully lowered the vacuum is applied through it to obtain finer detail than the initial elastic memory of the sheet gives. The plug in this method is actually the mould.

Bubble forming. The plug operates upwards in this method, but prior to the movement of the plug (which again is the mould), the heated sheet is blown up by a predetermined air pressure. The mould is then entered upwards into the sheet until it seals on the underside of the box when vacuum is applied from beneath to complete the cycle.

Air pressure forming. Heat is applied to the sheet (usually thinner gauges) by contact with a heated platen, which is mounted above a female mould, and the heated sheet is blown into this mould by air pressure entered through the heated platen which has previously moved downwards to clamp the plastic sheet. The sheet is usually of thin gauge and is fed from a roll. If necessary, a cutting edge can be incorporated in the top edge of the

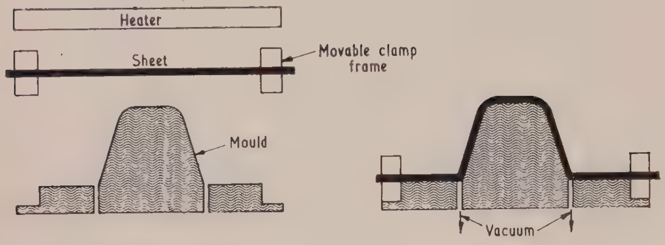
THE SIX MAIN METHODS OF VACUUM FORMING



(i) Negative forming

Heating cycle

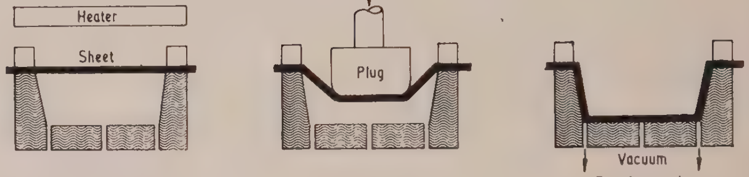
Forming cycle



Heating cycle

Forming cycle

(ii) Drape forming

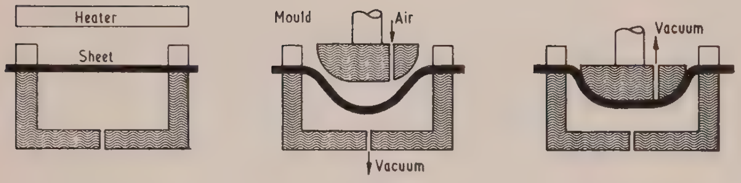


(iii) Plug assist forming

Heating cycle

Plug assist

Forming cycle

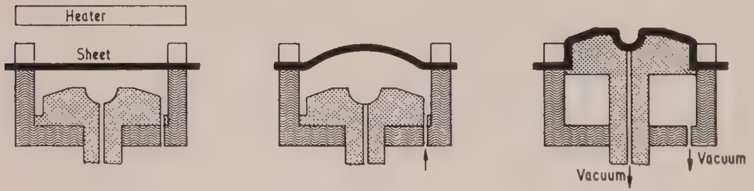


Heating cycle

Plug entry

Forming cycle

(iv) Vacuum snap-back forming

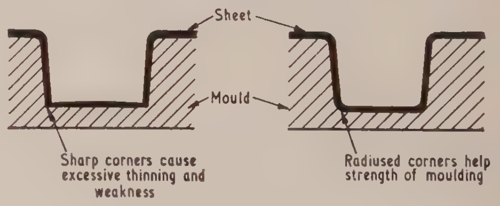


Heating cycle

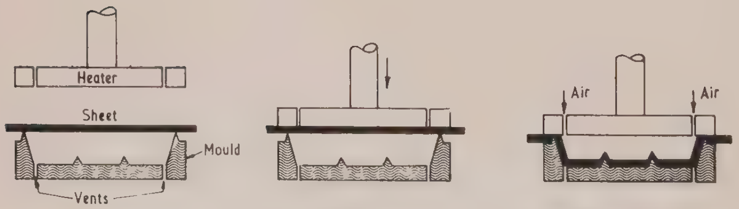
Bubble

Forming cycle

(v) Bubble forming


Sheet
Mould
Sharp corners cause excessive thinning and weakness
Radiused corners help strength of moulding

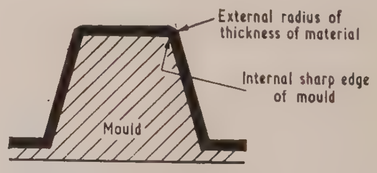
(vii)



Heating cycle

Forming & cutting cycle

(vi) Air pressure forming


External radius of thickness of material
Internal sharp edge of mould
Mould

Sharp internal edge of mould at top giving an external radius of thickness of material

(viii)

female tool so that a secondary downward pressure of the heated platen cuts the formed part from the web of material.

Moulds Required

Vacuum forming usually requires only a female or male half, which means that tooling time is considerably reduced when compared with injection or compression moulding. Moulds can be made from wood, or plaster for short or experimental runs of up to 50 off, but beyond this quantity more permanent forms of moulds, such as light alloy castings, machined metals, or cast plastic resins are necessary. Allowances must be made on moulds for shrinkage of the plastic moulding, which vary according to the type of plastic material.

Small vent holes, the diameter of which should be no more than half the thickness of the sheet used for forming, must be placed at all points on the mould where withdrawal of air is necessary to obtain close contour of the softened sheet to the mould surface. These vent holes can be opened out beneath the mould to increase the rate of evacuation of the air between the sheet and the mould.

Mould Design

When designing for the process it must be remembered that cast metal or machined moulds have an indefinite life and can be made to fairly close tolerances. Also, although undercuts should be avoided, these can be accommodated by the use of split moulds, or air and electrically operated withdrawal cores but, of course, the moulds are more expensive. Change of section cannot be obtained in vacuum forming, as the maximum thickness of the moulding is controlled by the original thickness of sheet. Radii, wherever possible, are preferable for this process particularly in the lowest corners of negative moulds where the sheet is prone to excessive thinning (see Fig. 7). Sharp corners can be obtained in contact with sharp edges or corners of a positive mould, but the natural radius on the reverse of this sharpness will usually be equivalent to the thickness of the material originally used (see Fig. 8).

Usually, a minimum draft of 2°—3° must be allowed on all moulds to facilitate withdrawal of the component and to obviate excessive thinning. Negative or female moulds are best designed for components where the design or embossing is on the side nearest the mould face or the exterior face of the moulding when formed, or where the depth of draw is shallow. Male moulds are necessary for deeper draws or where the internal measurements of the moulding are critical.

Further Design Considerations

When holes, piercings or openings are required in mouldings, it should be noted that these have to be a separate operation to the forming cycle. The base flash around mouldings can be cut away by steel knife cutters using a beam or hydraulic press, and with heavier gauge mouldings of any contour up to 36 in. diameter, horizontal trimming through the walls is now possible with a new automatic trimming machine developed by Omega Plastics Ltd., which will trim automatically whilst the operator is forming the next moulding. High or low speed routers may have to be used for interior openings or cut-outs in walls of mouldings, using jigs to hold the moulding in position whilst the cutting operation proceeds. Corners of cut-outs must have a radius of a diameter equal to the diameter of the cutter. Two-part mouldings can be adhered by using solvents of the particular plastic, although impact adhesive may have to be used when the two parts are of dissimilar materials.

Decoration is attained by spraying with appropriate inks or paints, or by preprinting the sheet before forming, although tests must be made in the latter case to ensure that colours do not change when heated, and several trials may be necessary to obtain the correct distorted design for registration. Inks used for preprinting must be capable of being stretched without undue loss of colour or opacity and to obtain the distorted pattern it is possible to form a sheet of material, colour this by hand, replace into the clamp frame under the heater, when it will return to its original flat state giving a copy of the pattern for printing.

Thermoplastic sheets can be pre-flocked to create a pile effect on the moulding after forming.

A new patent by Omega Plastics Ltd. enables metallic reverse engraved insignias or emblems to be produced by the vacuum forming process in full colour, if necessary, and with the solid effect created by the expensive process of diesunk injection moulded acrylics which are mask sprayed and vacuum metallized. This method is expected to effect considerable savings over the conventional method.

Thermoplastic Materials

All thermoplastic sheet materials are capable of being formed, although some are more difficult than others. The easiest types of sheet are the styrenes, acetates and some forms of rigid p.v.c. and its copolymers, whilst the more difficult ones are acrylics, polythenes, flexible vinyls, a.b.s. sheet and oriented styrenes, whilst polypropylene and polycarbonate are the most difficult. However, with growing techniques, conjunctions of the various methods of vacuum forming (see methods of forming) and better controlled forms of heating, all the aforementioned materials will not be beyond the processes of vacuum or pressure forming.

The characteristics of all thermoplastic material should be checked with sheeting manufacturers, as similar types vary slightly with different suppliers.

Applications in the Electronics Field

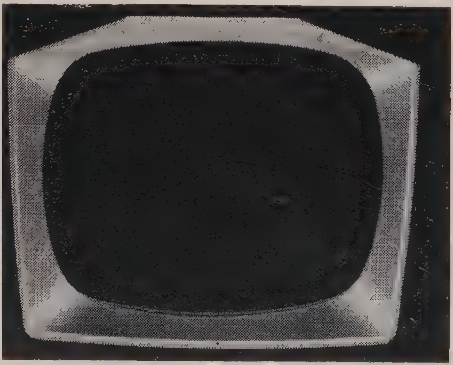
Radio and Television Cases and Trims. Radio cabinets, and in particular those for small transistorized battery operated types, can be easily formed as fronts and fitting backs, although certain restrictions must be observed with regard to front grille designs, as detail

SHEET THERMOPLASTICS SUITABLE FOR VACUUM FORMING
(with some approximate characteristics)

Name	Specific Gravity	Heat Distortion Temperature (°C)	Water Absorption 24 h (%)	Ft. lb./in.^{2} Impact Strength (Izod Notch)
Extruded acrylic	1·18—1·19	75—80	0·20—0·40	0·25—0·40
Cellulose acetate	1·28—1·34	55—65	1·6—2·0	1·2—2·0
Cellulose acetate butyrate ...	1·15—1·25	60—70	1·2—1·4	2·5—3·0
High impact styrene	1·04—1·06	80—85	0·12—0·15	1·5—2·0
Oriented styrene	1·05—1·07	80—90	0·04—0·06	3·0—3·25
L.D. polythene	0·925—0·94	80	0·1	5·1—6·0
H.D. polythene	0·935—0·96	110	0·1	5·0—15·0
Flexible vinyl...	1·2—1·4	—	0·1	—
Polyvinyl chloride	1·35—1·56	65—75	0·1—0·5	4·0—7·0
Vinyl copolymers	1·35—1·45	65—75	0·2—0·5	3·0—5·5
High impact p.v.c.	1·35—1·56	70—75	0·1—0·4	14·0—19·0
Acrylonitrile ... ... Butadiene styrene (a.b.s.) ...	1·05—1·24	80—90	0·02—0·03	5·0—7·0
Acrylonitrile ... Styrene copolymer ...	1·05—1·08	80—90	0·03	0·45
Polypropylene	0·90—0·92	140—150	0·03	2·5—4·0
Polycarbonate	1·20	135—140	0·2	12·0—16·0

such as that in injection moulding may have to be modified. A typically good example is where a vacuum formed front and back is used in conjunction with a plastic covered wood or metal central core, where the two plastic formings fit over the core and present a dual colour effect with the elimination of the usual plastic trim between the parts.

Masks for televisions are ideal for the process, as delivery is shortened by the speed and flexibility of tooling, time being reckoned in weeks instead of months as with injection or compression moulding. Designers are able to have prototypes within a few weeks for test and amendment, if necessary, at very low cost. A new type of inexpensive flock sprayed p.v.c. of thin gauge offers a new texture and medium for masks, the thin gauge being satisfactory when used behind the frontal safety glass panel. The futute of wooden cabinets, which can be plastic covered, for either radios, televisions or record players, seems assured now that the vacuum covering process is established. In this method a flexible textured p.v.c. sheet (which can be a two-colour print) is treated with a heat activated adhesive and clamped in the frame with the adhesive side towards the mould. The mould in this instance is the wooden cabinet which has also been treated with the heat activated adhesive. When the p.v.c. sheet has been heated to the correct temperature it is drawn down over the cabinet, or the cabinet is driven up into the sheet and finally suction is used to form the plastic sheet around the cabinet. The p.v.c. sheet adheres to the cabinet as the heat causes the adhesives to tack and bond together in the same process as the forming. Usually the cabinet is mounted on a plinth to provide an undercut at the lower edges, where the formed sheet tucks under and can be later trimmed away and adhered to the inside edges of the cabinet. This method covers a complicated form with no joins showing as with conventional hand covering.


21 in. television mask. Trims and masks formed from polystyrene or rigid p.v.c. are easily shaped to designers' needs.

Tape recorder deck. Intricate formings such as this tape deck are well within the scope of the process.

A new type of case can now be made by using a vacuum formed shell of rigid p.v.c. wherein the radio

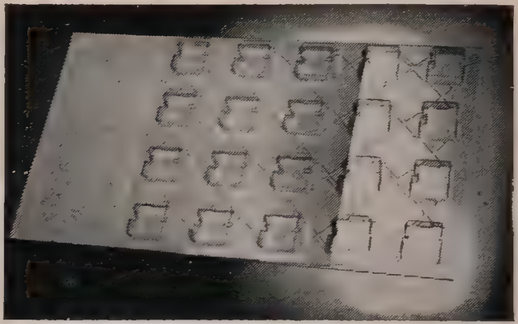
Special cases. A typical case for instruments. This type, where a formed p.v.c. insert is welded to a flexible p.v.c. folding outer, can be used for transistor radio cases.

Desk cover. Large or small covers formed from polystyrene, p.v.c., polypropylene or a.b.s. sheet are economical, attractive, and coloured right through the plastic.

Insulators. Formed from a multi-impression tool, these p.v.c. insulators combine light weight with good electrical and chemical resistant properties.

Assembly trays. Trays of all types for components can be made from many materials to suit various requirements. The tooling costs are low.

Special packs. Protective packs from cellulose acetate or p.v.c. are proving indispensable for the shipment of fragile, expensive components.



Assembly tray pack. A transparent clear cellulose acetate cover formed to hold intricate components safely, with a sliding board backing, provides a shipment pack easily converted to a tray for the assembly line.

Juke box cover. Here the base deck, lower trims, and rear trims are formed from polystyrene, whilst the clear front and top are acrylic. The chrome metal surround is the only non-plastic component.

chassis and front can be placed, this shell being high frequency welded into a flexible p.v.c. outer which can be made to close as a book, using press studs, forming a carrying case in addition to an operative shell case (similar to the micrometer case illustrated).

Tape Recorders and Record Players. In such products as these, complex forms such as decks and housings can be readily formed by vacuum forming with either a gloss, satin, textured or matt finish from the same tooling, by the use of differing surface finished sheet materials. Again, short tooling time and flexibility for design modification gives the process a head start on other methods. High-impact styrene, rigid p.v.c. and a.b.s. sheet are all suitable materials for these applications. In designing such parts, it should be noted that all cut-outs and openings are extra operations to the forming cycle, and that slots or openings are sometimes difficult to obtain economically in the vertical walls of the moulding.

Machine Covers. Covers for electronic equipment, battery cases and oscillograph hoods can be formed in one piece or two piece mouldings more economically than conventional metal shapings or fabrications which have to be stove enamelled to provide a durable finish. Vacuum formed covers have the original finish of the sheet coloured right through the thickness so that corrosion cannot take place. Insulation properties, too, are extremely good. Juke box covers, trims and component parts are further applications highly suitable for this process.

Special Packs. Specialized packs or trays formed from transparent cellulose acetate or p.v.c. which can be duplicated, placed together, and sealed by heat or h.f. welding, provide easy store recognition and perfect protection from damage for a number of components such as relays, pinches, guns or any delicate parts. The plastic impressions can be designed to contour closely or to provide clearance and cushioning for the components, and in some instances a board which slides into turned over edges of the plastic forming can replace the duplicate forming. Bubble packs formed from p.v.c., cellulose acetate or oriented styrene provide attractive, protective sales packs for replacement parts such as record player needles, styli and balances.

Another suitable method for packing kits or sets of components is by using a vacuum-formed high-impact styrene insert contoured to the parts which is held in a normal card box or carton.

Component Trays. Special purpose trays such as those illustrated can be designed for the process, enabling cavities to be formed which are contoured for the products and which will safely house them before, during assembly, and also in subsequent shipment if necessary. Flexibility in design and speed of tooling is again an asset with vacuum forming. Trays can be made from cellulose acetate, high impact styrene, polythene (in certain designs), acrylic, p.v.c., a.b.s. sheet and polypropylene, and in various colours for code identification. All these attributes plus clear transparent covers, if necessary, for easy store and stock checks, and the ease with which they can be stored or stacked make special purpose trays an asset to all component manufacturers. It should be remembered that cavities should be designed, wherever possible, so that the depth of each one is not more than half the minimum opening width, as generally such trays are formed by the negative forming process.

Other Applications

Small insulators, covers and cases for miniature batteries can be formed on tools with as many as 200 impressions and from 0·010 in. p.v.c. sheet, if necessary, giving minimum weight with high electrical properties and chemical resistance (see illustration). Thin walled high or low density polythene can be formed into winding core covers for the rear of television tubes, where a thin gauge is essential and cannot be moulded by any other process. With the advent of colour television and square-cornered tubes, items such as trim masks around the tubes will be required with a light absorbing surface to defeat the colour halo, and this is where a preflocked sheet subsequently formed will provide the answer.

Many further uses will be found for this versatile process, and vacuum forming, with its flexibility, will be found ready for the future advances of radio and electronics.

★ ★ ★

COMPONENTS FOR HIGH-FIDELITY EQUIPMENT

PART 1

By
John Borwick, B.Sc.

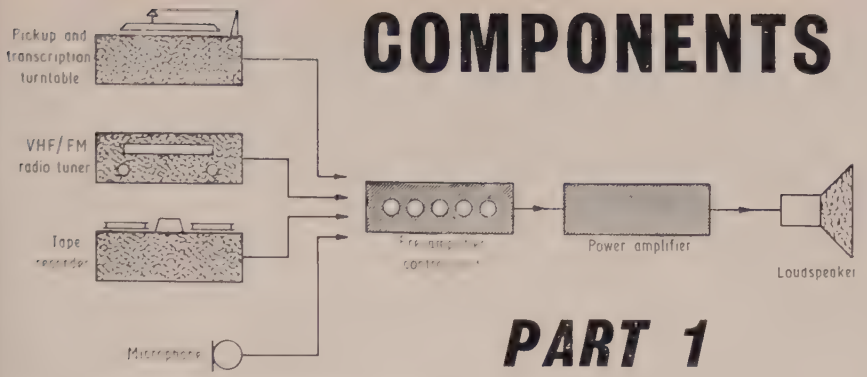


Fig. 1. The elements in a high-fidelity system.

Radio transmissions, gramophone records and tapes can now approach such a high degree of faithfulness to the original sound that the equipment used to reproduce them has to be designed and maintained to an equally high standard if it is to deserve the name "High Fidelity". Alongside the comparatively specialized field of the true high-fidelity amplifiers, transcription turntables, etc., there is now an unprecedented demand for "medium-fi"—something better than the kitchen radio—and it becomes necessary for supplier, customer and service engineer to examine the requirements of high-fidelity components and their performance. This first article defines high fidelity and outlines the gramophone record playing equipment. Tape reproducing equipment, amplifiers and loudspeakers are discussed in future instalments.

THE QUALITY of reproduced sound has greatly improved over the years. Recent milestones in this development have been the long-playing gramophone record, v.h.f./f.m. broadcasting, and magnetic tape recording. The availability of all this high-quality programme material has created a demand for reproducing equipment of equal excellence. When the reproduction stands up to at least a superficial comparison with the original sound it is called High Fidelity, and this is sometimes shortened to the tag "Hi-Fi".

The elements of a high-fidelity system are a gramophone turntable and pickup, radio tuner unit, tape reproducer or recorder/reproducer, pre-amplifier/control unit, power amplifier and one or more loudspeakers. The component requirements of each of these will be discussed in turn, but, of course, the important thing is the performance overall. Each element must be considered in relation to its neighbours. For example, a tape playback head produces a frequency/voltage response curve which rises 6 dB per octave over most of the range and then falls steeply. The tape playback amplifier therefore is designed not for a flat frequency response but one which is a mirror image of that of the head.

High-fidelity Criteria

The subjective assessment of the quality of reproduced sound is an inexact business, and what pleases one listener may pain another. But objective criteria do exist, giving the designer and the service engineer the parameters and check points they need. The loudspeaker is the last link in the chain, whatever the source of programmes, and cannot at present be specified to the same rigid tolerances as the other elements. Its performance is, in any case, influenced by the room and its exact placement in the room, and so most of the following figures refer to the reproduction chain up to the point at which the loudspeaker converts the electrical signals back into actual sound.

Frequency response: should be 30—20,000 c/s, but a range 40—15,000 c/s will meet most requirements. Variations in level within the range should not exceed ±1 dB, and the amplifier should have a useful output up to say 40,000 c/s to avoid ringing on transients (see below).

Dynamic range: should be 60 dB or better between an upper limit where distortion sets in and a lower limit where the noise level becomes noticeable. Broadcasts in this country are still compressed to about 30 dB, but disc and tape records are now made with dynamic ranges of up to 60 dB or more.

Transient response: the system must respond quickly to sound peaks and have no "hang-over". The requirements for this are good frequency response, zero phase distortion and adequate damping in filter circuits, transformers and the loudspeaker itself.

Harmonic distortion: not more than 1%.

Intermodulation distortion: not more than 3%. Both these forms of distortion are introduced by non-linearity in valve characteristics, pickups and loudspeakers. They produce spurious signals at multiples of the fundamental or sum and difference frequencies.

Mains hum: should be inaudible.

Noise: should be 60 dB below the maximum undistorted power level (see "Dynamic range" above).

These requirements are much more stringent than those for a domestic radio, where the frequency range is rarely better than 100—6,000 c/s ±10 dB with distortions approaching 15—20%. They can be met only by careful electronic and mechanical design and the use of top-grade components. As we shall see in a later article, the design and construction of amplifiers to meet the above specifications have remained comparatively static for a number of years, though new developments in transistor application are now beginning to take place.

On the other hand, the transducers, that is the pickups, tape heads, microphones and loudspeakers, are all in a state of continuing development.

The introduction of two-channel stereophonic recording, and experimental stereo broadcasts, made twin amplifiers necessary. This added two more high-fidelity requirements, *viz. channel balance*: should be accurate to ±1 dB, and *channel separation*: should be —25 dB or better. Amplifier circuitry, however, remained basically the same, though entirely new gramphone pickups had to be designed.

Components for Disc Reproduction

The modern long-playing gramophone record became possible about 1950 when vinyl plastic materials allowed slower playing speeds (33⅓ and 45 revolutions per minute instead of 78) and smaller grooves (0·002 in. wide instead of 0·006 in.). This extension of playing time from some 4 minutes per 12 inch side to 25 minutes was achieved with a handsome reduction in surface noise and improved frequency range. These advantages could only be obtained, of course, with redesigned pickups and styli.

Sapphire-tipped styli had already been introduced for 78 r.p.m. records, and now became standard for LP's and of a narrower gauge, i.e., a tip radius of 0·001 in.—referred to as a "one thou stylus". Sapphire, real or synthetic, is aluminium oxide and a very hard material indeed, but the abrasive forces in playing records are severe so that the life of a sapphire stylus is not much more than about 100 LP sides.

Diamond styli are better for high fidelity, having a playing life of 1,000 hours or more so that the risk of a "flat" developing and ruining a precious record is much reduced.

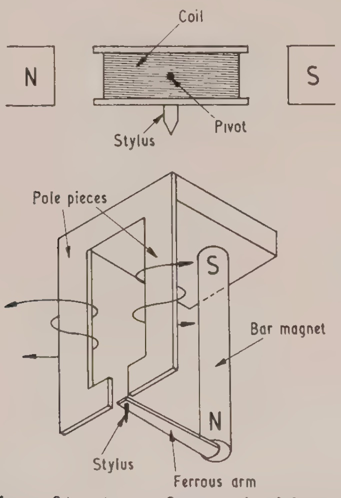


Fig. 2. Comparison of two types of magnetic pickup: the moving coil (top) and variable reluctance (below) in which stylus movements alter the reluctance in the magnetic circuit formed by the magnet, pole pieces and ferrous arm.

When stereophonic discs were introduced in 1958, the recommended stylus size became 0·0005 in. (half thou), obtainable in sapphire or diamond. A compromise radius of 0·0007 in. is sometimes used so that stereo or conventional single channel discs can both be played with the same stylus. All stereophonic pickups will play these monophonic discs, but the half thou stylus is liable to reproduce more noise, particularly if the disc has been frequently played with a one thou stylus.

The weight of gramophone pickups was strikingly reduced when LP discs arrived. The pre-war weight of about 4 oz. (110 gm) dropped to 12 gm or less. High-fidelity pickups are now designed to track at between 3 to 8 gm, and special models exerting a downward pressure of only 1 gm are available. The wear on stylus and disc is therefore almost negligible, provided that discs are kept scrupulously free from dust.

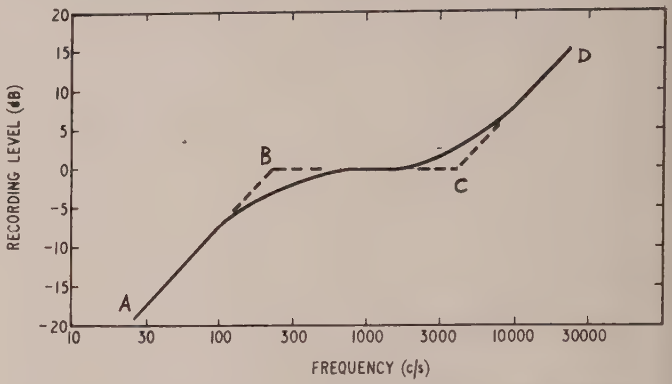


Fig. 3. The disc recording characteristic follows constant amplitude from ***A*** **to** ***B*** **(i.e. rises 6 dB per octave on a velocity graph), and is given treble pre-emphasis from** ***C*** **to** ***D*****.**

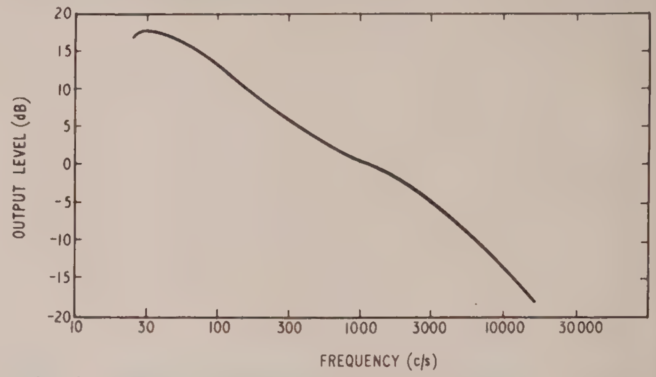


Fig. 4. Constant velocity magnetic pickups produce an output which follows the characteristic of Fig. 3, and so must work into an equalizing network giving the above replay characteristic.

The sensitivity of gramophone pickups is quoted as so many millivolts for a standard recorded velocity of 1 cm/s, and varies very much from one type to another. Magnetic pickups are best for high fidelity, in spite of their relatively low sensitivity which requires an amplifier rated to accept inputs as low as 3 mV—almost the lowest signal which can be carried along screened cables in the vicinity of power wiring without serious hum induction. Magnetic types include moving coil, moving iron, moving magnet, variable reluctance and ribbon. They all have the same basic electrical characteristics, namely low or medium impedance (making a matching transformer necessary in nearly all cases) and approximately constant velocity response.

The velocity/frequency characteristic employed for all disc recording nowadays slopes upwards from bass to treble. The bottom section is constant amplitude, then there is a flat section until high frequency pre-emphasis comes in, again at approximately 6 dB per octave. It follows from this that magnetic pickups all have similar equalization requirements. That is, they must work into a circuit which produces a mirror image of the recording characteristic by boosting the bass and attenuating the treble.

Crystal and ceramic pickups are used universally for ordinary domestic quality record players and, in a few cases, have been brought to a sufficient degree of development to qualify as high fidelity. They are several times more sensitive than magnetic types, a typical output rating being 50 mV/cm/s. Also, they are high impedance devices and so can be taken to the valve grid direct. In terms of equalizing, they are much less demanding than the magnetic pickups. Their response is essentially constant amplitude, so that they transform the upward sloping recording characteristic into a flat response automatically. It is very important, however, that the impedance loading of crystal and ceramic pickups follows the recommendations of the manufacturer.

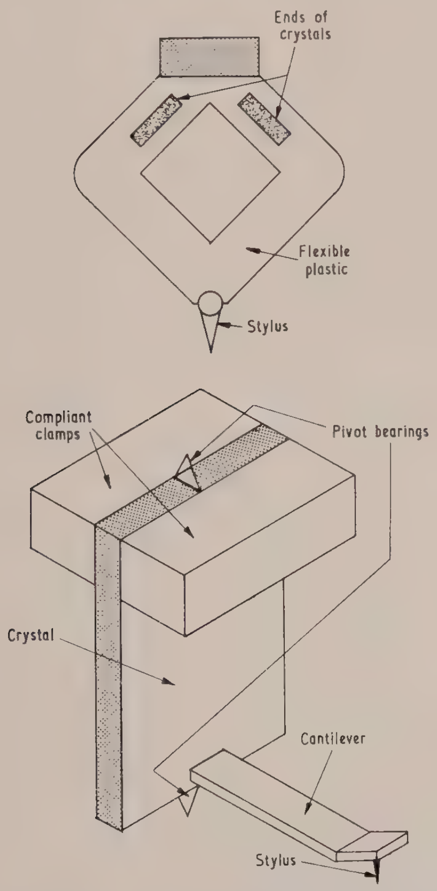


Fig. 5. Comparison of two types of crystal pickup: a simple cantilever model (below) and a stereophonic version (top) in which stylus movements simultaneously apply torsional forces to two crystals mounted mutually at right angles.

Pickup Arms

All disc reproducers which use a pivoted pickup arm (and that means all except a few used in broadcasting and theatres) suffer from two inherent forms of distortion. Firstly, there is a steady reduction in the speed at which the disc passes under the pickup as it tracks towards the centre. This speed is the product of the groove circumference (πD) and the number of revolutions per minute. The diameter D falls from approximately $11\frac{1}{2}$ to $4\frac{3}{4}$ from the outside to the inside of a 12 in. disc, so that the recorded waveform becomes progressively more cramped towards the end of each side. The main effect of this is loss of high frequencies, though this can be partly compensated for during the cutting process by introducing increased pre-emphasis as the cutter head tracks towards the centre.

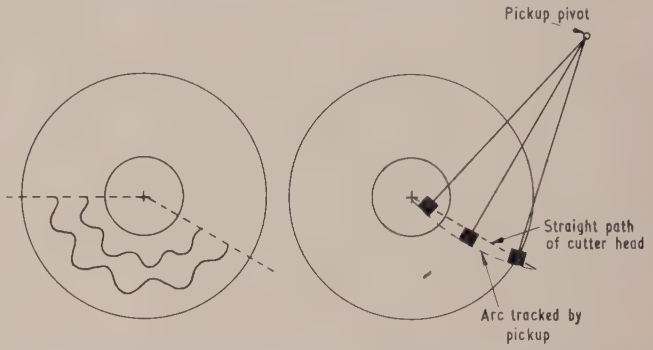


Fig. 6. Distortions inherent in disc reproduction include "end of side" distortion (left) due to the reduction in disc/stylus speed towards the centre, and "tracking error" (right) due to the pivoted arm producing an arc instead of the straight line followed by the cutter head.

The second distortion, called tracking error, is due to the fact that the pickup does not follow the same path over the record as did the cutter head. The cutter tracks in a straight line along a radius, whereas the pivotted pickup arm traces out an arc. The effect of this is to introduce severe second harmonic distortion, and it is to keep this to a minimum that high quality pickups have the head cranked at an angle to the arm—called the offset angle—and they are mounted so as to overhang the centre spindle slightly. Three special designs of arm are available which eliminate this tracking error. The first of these uses a straight line gantry or bridge to carry the pickup head over the disc. The second has a twin arm assembly which rotates the head during playing so that it preserves the correct playing angle. The third achieves a similar effect through a shaft down the centre of the main arm.

With playing weights well under 10 gm, it follows that friction at the pivot must be negligible, and that the lateral compliance of the stylus must be very large.

Transcription Turntables

The turntables used for high fidelity reproduction are usually referred to as transcription turntables because of their affinity to the gramophone units used for the professional transcribing of disc masters. They invariably have a heavy turntable disc a full 12 in. in diameter. The weight is designed to iron out short-term speed fluctuations by its flywheel effect. These fluctuations are called "wow" if occuring 20 times per second or less, and "flutter" if they occur at faster speeds. The most likely source of flutter is eccentricity of the drive capstan or its associated roller. Transcription motors are almost invariably of the induction type—though a few are truly synchronous. They are usually four pole, running at a fixed speed of say 1,320 revolutions per minute.

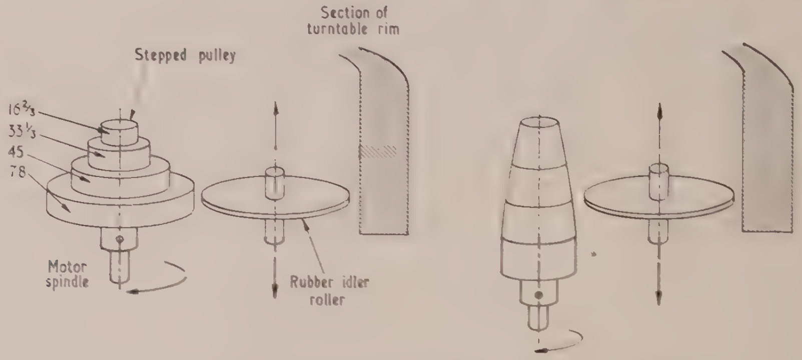


Fig. 7. Variable speed turntable drives usually employ a stepped diameter pulley (left) the speed being selected by vertical shifting of the rubber idler roller. A conical pulley (right) is occasionally used, giving continuously variable control of speed.

The drive is usually transmitted to the rim of the turntable direct or through a rubber-tyred roller. Selection of the various speeds (78, 45, $33\frac{1}{3}$ and $16\frac{2}{3}$ r.p.m., the last named being used for only a few discs of American origin) is achieved through a stepped pulley on the motor shaft or interpolated between the capstan and the roller. Where continuously variable speed is required—as for example on the Goldring-Lenco turntable—the pulley is cone shaped. Fine adjustment of the speed, to allow for mains frequency fluctuations or pitch discrepancies on individual records, is sometimes incorporated. This takes the form of an eddy-current brake. The capstan simultaneously drives a metal disc which rotates in the field of a small permanent magnet. Adjusting the position of this magnet changes the load on the motor to give speed control over a range of the order of $\pm 2\frac{1}{2}\%$.

To be continued: the next article will be concerned with high fidelity from tape and radio.

ELECTRICAL ENGINEERS EXHIBITION 1962

On Thursday, 28th September a Dinner was held at Grosvenor House in London as a preliminary to the Eleventh Electrical Engineers Exhibition, organized by The Association of Supervising Electrical Engineers and to be held at Earls Court, London, 20th—24th March, 1962.

The main themes of the speakers at the Dinner were, firstly, the importance of design in the electrical field and, secondly, the necessity for complete reliability in all electrical systems, circuits and components. In the latter connection, particular emphasis was placed on the reliability of electronic systems in aircraft and the urgent need for greater research in this particular field.

In view of the ever-increasing importance of electronics in the aircraft industry, it has been decided to introduce a special feature at the Exhibition entitled "Electricity in Aviation". A part of this will be devoted to the Royal Air Force.

Over the years, the A.S.E.E. Exhibition has provided Great Britain's Electrical Industry with a useful and impressive "shop-window" in which the developments of the industry could be displayed to interested persons throughout the world. The organizers have built up a considerable overseas mailing list, and it was stressed at the Dinner that it was important for Exhibitors to submit, as early as possible, full details concerning the design features and the technical merits of their exhibits in order that these could be given effective overseas publicity. It was revealed that, of the 76,000 people who attended the 1961 Exhibition, 800 were visitors from a total of 88 different countries.

As in the past, admission will be restricted to ticket holders and the general nature of the Exhibition is to be unaltered. There is, however, a possibility for the future that exhibits may not be confined to goods produced in the United Kingdom. This is due to probable entry of Great Britain into the European Common Market and the fact that a number of British manufacturers may set up production units in Europe. No changes in policy will be made, however, until the organizers are satisfied that such changes would be in the general interest of all concerned.

HOW THE LIGHTNING IS BUILT

Press Visit to the British Aircraft Corporation's Lancashire Works

PROGRESS in the design of electronic and radio components is very much conditioned by the demands of the aircraft and guided missiles industries. An opportunity to see at first hand how modern military aircraft are manufactured was given to the Press recently when the Lightning aircraft factories were visited on Wednesday, 12th July. The English Electric Lightning is the most technically advanced aircraft in service and indeed was the first operational supersonic fighter. It has a maximum speed of more than twice the speed of sound and has been coming off the production line at Samlesbury, Lancashire, since 29th October, 1959.

A fighter of this type is even more crammed with electronic equipment than its civil contemporaries. In addition to the master gyros and other instrument controls there is the equipment for control and firing of the air-to-air guided missiles, target location equipment and the receiving end of important ground-to-air services.

We were shown the three major factories of the English Electric Company at Preston, Accrington and Samlesbury, the wings and front fuselages being made at Preston, the main fuselages and tail planes at Accrington. The aircraft is then finally assembled at Samlesbury, whose runway allows the planes to be flown away to the neighbouring test field at Warton, but cannot be used for landings. We found that electronic techniques are no less important in the assembly and testing of the Lightning than they are in the finished product. For example, the operations of cutting and routing the steel plates can now be controlled by a specially programmed magnetic tape. The traditional method for controlling such machines is to use a template. The operator runs a guide round this prepared shape so that a mechanical link causes the milling and drilling tools to cut the metal sheet correctly, chamfer edges and drill all the necessary holes. In the new technique a drawing is prepared and sent to the tape programmers who record appropriate signals on ordinary $\frac{1}{4}$ in. magnetic tape. After placing each uncut sheet in position, all that the operator does is to switch on the tape device. This instructs the machine on the various operations in sequence, and may be replayed to repeat this exactly on as many plates as required, with considerable saving in time and the need for skilled personnel.

The continuing miniaturization of electronic components has introduced the new term "components density" and this concept is reflected in the manufacture of aircraft. We were told that the "equipment density" of the Lightning was much greater than that of conventional aircraft and indeed extreme compactness is one of the Lightning's special features. A considerable use is made of the inter-skin spaces throughout the wings and fuselage to house hydraulic, fuel and electronic apparatus. A system of colour coding and equipment boxes labelled for each aircraft ensured that all components were accounted for at each stage in the construction. The fitter vacuumed out the fuselage at the end of each spell of duty and, in addition, a special jig allowed the entire structure to be rotated to remove any scraps of wiring which escaped the vacuum cleaner.

The cockpit itself is so tightly packed that only one fitter can work in there at a time. This has increased the number of working days and made a special test procedure necessary. Two inspectors are employed, one to work in the cockpit and another to check readings on a duplicate instrument board which is connected to the cockpit instrument proper prior to all final tests. An ordinary type of aircraft intercom set keeps the inspectors in headphone contact with each other while each piece of equipment is checked in turn.

No less than 3,000 test flights were carried out during the development of the Lightning and here, too, special electronic equipment was used. Simultaneous with the tape recording of the pilot's verbal commentary and messages passed to him from the ground, a telemeter track was made. Thus any part of the recording could be played back as often as required and at the same time the actual meter readings on the cockpit dials could be reproduced from the telemeter signals on to a display board of instruments. We were given a demonstration of this from a tape in which the pilot took the Lightning through a series of manoeuvres and it was possible to confirm by watching the meters, each point in the aircraft's movements in step with the commentary, although the recording had been made quite some time previously.

To round off the visit, Mr. R. P. Beamont, Manager of Flight Operations, gave a flying display as part of an actual test flight. He flew low over our heads several times and demonstrated the Lightning's ability to turn in a very small radius and its high rate of climb. The aircraft he used was the first Lightning Mark II, described as having better performance in range, speed and altitude, more advanced electronic equipment, and an improved air-to-air guided weapon. It had come off the assembly line only the day before.

ELECTROCHEMICAL POLISHING OF SEMICONDUCTOR WAFERS

A RESEARCH SCIENTIST at the Bell Telephone Laboratories in the United States, has developed a new electrochemical technique for rapid, scratch-free polishing of germanium and silicon wafers for transistors. The method is said to be much faster and more efficient than conventional polishing methods. In addition to the anticipated savings of more than 50% of the polishing cost there is a distinct improvement in the electrical characteristics of certain types of devices.

One of the major problems in the manufacture of transistors is the maintaining of an undamaged surface on the semiconductor slice used for the active element of the device. In conventional manufacturing practice, these slices are prepared in four steps. First they are sawed from a cylindrical single crystal, then they are lapped with a coarse abrasive, and polished on optical lapping machines. These three operations produce a smooth, flat surface. In the final step, the slices are etched to remove all the residual mechanical damage to the crystal face caused by abrasive action.

When there are deep scratches from lapping and polishing, the etchant cannot remove all the damage, and poor-quality transistors result. In contrast, electrochemical polishing does not introduce new damage during processing.

In the new technique, semiconductor slices are mounted on a non-conducting disk. After electrical contact is made to the slices, they are placed on a polishing wheel over which an electrolyte flows. When the polishing wheel rotates, a film of electrolyte, the thickness of which is determined principally by the viscosity of the electrolyte, separates and automatically maintains the semiconductor at a relatively constant distance from the wheel.

The electrolyte used for the electropolishing of germanium is dilute potassium hydroxide, and dilute hydrofluoric acid is used for silicon. For *n*-type material, either germanium or silicon, it is desirable to illuminate the semiconductor surface during electro-etching.

The smoothness of the surface obtained by this method is apparent through study of photomicrographs of comparative surfaces. A mechanically polished surface shows distinct scratches when magnified 500 times. These scratches are caused by broken pieces of abrasive and semiconductor, which are ground into the face of the polished slice. On the other hand, semiconductor slices polished by this new technique show no texture that can be associated with surface roughness even under electron-microscope examination at 53,000 power.

Examination of three electrochemically polished germanium wafers. When the polishing device operates, the electrolyte (in the glass container) drops onto the rotating wheel shown in the foreground.

International General Electric Company of New York

MICROWAVE AMPLIFICATION OF SOUND WAVES

THE DIRECT AMPLIFICATION of sound waves using microwave radio energy as a power source has been demonstrated for the first time by United States General Electric Company at its Research Laboratory.

Amplification of the sound waves, called phonons, is accomplished by "stimulated emission" of energy by atoms as they change from a higher to a lower energy level. This is the same mechanism used in Maser (Microwave Amplification by Stimulated Emission of Radiation) to amplify electro-magnetic radiation. The new phenomenon has been termed the "phonon Maser effect".

According to Dr. Guy Suits, the Company's Vice President and Director of Research, this is the first time that stimulated emission has been successfully used to amplify energy other than electro-magnetic energy. Dr. Suits noted that although there is no immediate commercial application of the phenomenon, it provides a significant extension of the principle of stimulated emission, and represents an advance in understanding of solid state physics.

The technique may also provide a valuable research tool permitting experimental study of the role of phonons in many physical phenomena. For example, it may make possible an acoustic oscillator for generating sound waves of higher frequency than are now attainable.

In both Maser and the new phonon Maser effect, atoms are raised to a high energy state by irradiating—or "pumping"—them with high-frequency electro-magnetic energy. Then, when signal energy of a lower frequency is introduced, stimulated emission of the signal frequency occurs. Under the proper conditions, the stimulated emission may be strong enough to produce amplification of the signal. In Maser, the pump, signal and output are all electro-magnetic energy, whereas in the phonon Maser effect only the pump is electro-magnetic energy, and the signal and output are both sound, i.e. mechanical energy.

The effect has been demonstrated with short pulses of very high-frequency sound (9·3 kilomegacycles) in a ruby crystal (which consists of alumina (Al_2O_3) with chromium ions as an impurity). When it is subjected to a magnetic field, the electrons on the chromium ions, acting as small magnets, tend to line up with the field. The electrons have four characteristic energy levels, corresponding to how closely they line up with the applied field. Most of the electrons are in the lowest energy level, but can move to higher energy levels by absorbing energy at a certain resonant frequency, which is set by the magnetic field strength and the characteristics of the electrons in the crystal. The reverse transition, from a high to a low-energy level, can be made by emission of energy at the resonant frequency.

There is also interaction between the vibrations of the atoms in the crystal lattice and the energy states of the electrons, due to the electric fields of the atoms in the lattice. As the atoms vibrate, the electric fields acting on the electrons vary and this affects their energy levels. It is this interaction which makes the phonon Maser possible.

To achieve amplification by the phonon Maser effect, as in conventional Maser, most of the electrons are raised two energy levels above the lowest by pumping with electro-magnetic energy at a frequency which causes this transition (23 kilomegacycles in this case). Then, when energy at a lower frequency is introduced, stimulated emission occurs.

The work of the General Electric Research Laboratory has permitted direct observation and accurate measurement of the effect for the first time. The phonon amplification observed is about 12% per cm of ruby. This is probably enough to overcome losses from crystal imperfections and deviations of the ends of the crystal from perfect flatness and parallelism. To achieve high amplification, the waves must be reflected back and forth through the crystal many times, being amplified a little each time. The ends must be flat and parallel, or else the waves will be reflected unevenly and will interfere with each other. The ruby crystal is kept at a temperature of about 1·5° above absolute zero to minimize the effects of thermal vibrations.

SOLAR CELL INSTALLATIONS

Trinity House Development for Marine Buoy Lighting

Close-up of a bank of Ferranti solar cells in a light buoy at the Corporation of Trinity House experimental establishment at Dungeness, Kent.

MANY of the potential applications for silicon solar cells such as the sun-powered motor car or vacuum cleaner are still a figment of the scientist's imagination and are not considered to be either as efficient or as economic as existing engineering methods. But this will not always be the case. Indeed, in the next few years it seems likely that silicon solar cells will be widely employed to provide power for re-charging batteries for marine buoy lighting.

Considerable efforts are currently being made in this direction by research engineers of Trinity House and already a number of experimental installations have been built both at Trinity House and at their research station at Dungeness, Kent. The Corporation of Trinity House dates back to 1514 and is responsible for the maintenance of lighthouses, lightships and marine buoys around the coasts of England and Wales.

At present, marine buoy lighting relies almost entirely on the use of stored gases, such as propane or acetylene, the gas being used not only to provide the light, but also to control the character of the flash. Systems like this have been in use for many years and have proved extremely economic and efficient. It is necessary, however, to replace the gas cylinders, often under adverse weather conditions, approximately every 12 months.

With the advent of the silicon photo-voltaic cell, or as it is more commonly known, the solar cell, which converts energy from the sun or from incandescent lamps into electrical energy, Trinity House research engineers turned their attention to its possible application to marine buoy lighting. They recognized that the use of the solar cell would be advantageous, particularly from the maintenance viewpoint, because of its extreme reliability. Indeed, there appears to be no special reason why such a cell should ever fail and experiments carried out by the manufacturers Ferranti Ltd., bear this out, for over a period of 20,000 hours there is no evidence of change in the device. It has a response time of a few microseconds and can operate without deterioration under conditions of high temperature (−40° to +125°C) and humidity.

Solar cells were first produced some years ago at the Bell Telephone Laboratories in the U.S.A. When used as a means for the direct conversion of solar energy to electrical power, they form the most efficient power source yet known. Efficiencies of the order of 6 to 10% for the conversion of light energy to electrical energy have been achieved.

Ferranti Ltd., were the first manufacturers in the United Kingdom to produce cells of this type to act as photosensitive devices in punched tape and card readers for industrial control and instrumentation. This range has subsequently been enlarged to include types suitable for power generation.

In their planned programme of research, which is of necessity long-term in nature, Trinity House research engineers have already established practically that despite the unfavourable English climate, solar cell installations can provide the necessary power throughout the year to charge a small battery. However, because of the many problems still to be solved, they do not anticipate that the first fully-equipped marine buoy installation can be available for operation before the end of 1963.

Experimental equipment which has already been

Continued on page 780

NEW BOOKS

The Physical Theory of Transistors

By L. B. Valdes.

370 pp. McGraw-Hill Publishing Co. Ltd. Price 81s. 6d.

Semiconductor Devices and Applications

By R. A. Greiner.

493 pp. McGraw-Hill Publishing Co. Ltd. Price 97s.

IN CONFORMITY with the title the first of these two books deals with the more physical side of transistors. To help clear the way to an understanding of the concepts, developed in the later parts of the book, an elementary introduction is given in the first four chapters. In this part one is reminded, amongst other things, of crystal structure and lattice defects, of minority and majority carriers and of the flow of holes and electrons.

The major part of the book is in the second section, which starts with a clear discussion of electron energies in semiconductors.

The section dealing with crystal momentum and Bloch wave functions is perhaps too short and is rather difficult to understand. However, the Fermi energy level is very well treated and one is left in no doubt as to its importance.

Various general current and charge relationships are next derived and the flow of current in semiconductors is then treated carefully. As one would expect in such a book, *p-n* junctions are fully examined. This part of the text ends with an interesting chapter on surface properties.

In the third section the electrical characteristics of diodes and of junction transistors are first examined from a physical standpoint. The mathematics of small signal transistor theory follows and is then applied to specific semiconductor device structures. Finally, the high-frequency characteristics of transistors are examined and, in the last chapter, special structures are briefly explored.

In this book a successful attempt has been made to gather together into a useful form a large amount of information relating to the design of transistors. The curious-minded, the transistor student and those actively engaged in the development of transistors should all find this book of real value.

Dr. Greiner is to be congratulated for writing the second of the books under review. This is a text-book which is written at a level suitable for university students. The reader is first conducted slowly and carefully through the basic physical concepts used in describing crystalline substances. Particularly well described are the processes of particle diffusion and drift. The large number of excellent diagrams and illustrations are a considerable asset in these introductory stages of the subject.

Following a concise but nevertheless clear description of the preparation of semiconductors and the measurement of their properties there is a section devoted to contacts in distinction to junctions, which are examined in the next chapter. Diodes and the basic mechanism of transistors are then examined from an essentially physical viewpoint.

The second half of the book starts by describing the characteristics of transistors and leads naturally onto their use in practical circuits.

In the chapter on small signal amplifiers, standard circuit analysis is applied to the preceding results to derive the usual relations for amplifiers. Emphasis is placed upon the effects and necessity of feedback within a circuit. Thermal stability and signal distortion are considered under the heading of power amplifiers.

The succeeding chapters deal with the various basic elements such as d.c. amplifiers, oscillators and switching circuits. An unusual and good section is that on power supplies.

The high-frequency limitations of simple diffusion transistors are examined from a practical standpoint and leads to a discussion of the "mesa" type of structure. Finally, switching-mode circuits are described.

Besides providing a good foundation in transistor circuit theory this book will also be of use in the laboratory.

F. M. RUSSELL

Packaging Directory, 1961

305+69 pp. The Tudor Press Ltd. Price 21s.

THE 1961 EDITION of this Directory is the fourteenth to be issued and has an increase of 81 pages of text compared with the 1960 edition. The contents are divided into six sectionalized main divisions which are as follows:

> Index; Buyers' Guide (1. Containers and Closures; 2. Materials; 3. Packaging Machinery and Equipment; 4. Mechanical Handling; 5. Services); Organizations, Associations and Consultants (1. Official Organizations; 2. Design Organizations and Associations; 3. Packaging Consultants; 4. European Packaging Federation Members); Foreign Firms with British Agents; Alphabetical List of Trade Names; Alphabetical List of Names and Addresses.

The Directory is very comprehensive and should be invaluable to those people concerned with the field.

Semiconductor Abstracts Vol. 6

By J. J. Bulloff and C. S. Peet

528 pp. John Wiley & Sons; London: Chapman & Hall Ltd. New York: Price 112s.

WITH the vast quantity of literature published on this subject, this sixth volume of a compilation of abstracts should prove invaluable to all scientists who are involved in research or development of semiconductors. In the foreword it states, "abstracts are more useful if they are current". It is to be regretted that three years have elapsed between the literature reviewed and the publication of this book in the United Kingdom. Although during the interval new materials, theories and applications have taken place, this volume, with nearly 2,000 abstracts covering the whole field of semiconductors, should find itself on many literary shelves as a reference book.

Each of its eleven sections are clearly printed and systematically arranged. The first seven sections, covering just over half the abstracts, deal with elemental semiconductors, halides, oxides, chalcogenides, intermetallics and a short section on organic semiconductors. The remaining abstracts cover the literature dealing with the theory and applications. Each section is sub-divided to cover all aspects of the main title, e.g. the section devoted to halides is sub-divided into six parts and deals with each of the alkali halides individually, with subsequent sub-sections dealing with silver and other halides.

It is inevitable that in a book of this kind there should be some doubt as to where a particular title should be included; the user of this book, however, should find the 57 pages devoted to the index of both authors and subjects, adequate and reliable.

The real value of a book of this nature depends on the technical evaluation of the literature reviewed and the quality of the abstract subsequently prepared; the authors in this case must be congratulated on their clear and concise presentation.

J. Day

Fuel Cells

Edited by G. J. Young

154 pp. Chapman & Hall Ltd. Price 46s.

THE VOLUME under review contains the papers presented at a Symposium on Fuel Cells organized by the Gas and Fuel Chemistry Division of the American Chemical Society at Atlantic City in September 1959. After 100 years of research this was probably the first occasion on which information on cell construction and performance was presented in a fashion which permits comparison and an assessment of general feasibility.

Chapter 1 gives a brief general introduction to the subject. This is followed by an examination of the catalytic action of different metals which might be used as fuel and air electrodes. The next chapter reviews this subject with a theoretical exposition of the kinetics of electrode processes.

Low temperature fuel cells are authoritatively covered by Kordesch, who is now working with Union Carbide in the U.S.A. Progress can best be summarized by the following achievement:

"Two years of intermittent service have been achieved on 10 mA/cm² and over one year of continuous service on 20 mA/cm² at 0·8 V, with tests still in progress."

In addition it is fair to mention that the cell has given short-term results at a loading of 250 mA/cm². Clearly this cell will find specialized applications which are not strictly commercial.

High temperature fuel cells aimed at "providing electricity direct from coal" have been described in separate chapters from four independent teams working at the Central Technical Institute at The Hague, the Sondes Place Research Institute in England, the Consolidation Coal Company in Pennsylvania, and the G.E. Research Laboratory at Schenectady. It is surprising to find how closely the techniques and results resemble each other. The Dutch paper makes it clear how difficult it is to compare the performance from small-scale experiments, but it is probably fair to say that the current densities do not match those achieved on cells working at lower temperatures. However, a much wider range of fuel gases is usable.

The paper by Mr. F. T. Bacon gives an account of the British work on the high pressure oxygen:hydrogen fuel cells which provide a compromise between the difficulties of high temperature operation and the limitations of the low reaction rates at low temperatures. This work is the most advanced and has now progressed to the stage where a 5 kW unit has been developed and power densities of 10 kW/ft.³ are feasible.

The final chapter gives a summary of the discussions, but it seems that the Editor has missed an opportunity of providing a more authoritative status report. Reading between the lines it appears that high temperature fuel cells for a central generating station are still a rather remote possibility. The Bacon medium temperature cell might have practical applications for traction purposes, particularly if it could be made to work on condensible gases such as methane. This topic is ripe for a feasibility study. The immediate problem probably is to find an application which will justify the costs of further development.

H. W. Davidson

The Advance Science Masters Handbook

Compiled by Ivan L. Muter, B.Sc., A.M.I.E.E., A.Inst.P.

124 pp. Advance Components Ltd.

ADVANCE COMPONENTS LTD. have obviously taken a great deal of trouble over the preparation of this *Handbook* and both Advance and Mr. Muter are to be congratulated for producing this concrete example of how Industry can invest in the future.

The *Handbook* is arranged in two parts, the first devoted to theory and reference material, and the second to laboratory experiments and demonstrations. Both parts are sub-divided into numbered sections, each dealing with a specific subject, group of subjects or applications. The sections in Part Two are further sub-divided into particular experiments, each with a specific number for quick reference. A cross-reference is provided at the back of the book.

Each of the 47 experiments has been carefully devised to suit the particular requirements of the school laboratory. Each experiment will suggest other applications and it is the publisher's hope that much time-consuming verbal and blackboard instruction may be reduced.

In his Introduction, the Managing Director of Advance Components Ltd. writes:

"We in the Electronics Industry are very conscious of the problem that is forcing itself on us with ever-increasing intensity as the years pass—to find the people with the right qualifications for research laboratory, development work, production control and kindred activities. It is to these future technicians and to those instructing them today that we dedicate this volume".

Electronics: A Bibliographical Guide

By C. K. Moore and K. G. Spencer.
xvii + 411 pp. Macdonald & Co. Ltd. Price 65s.

THIS BOOK has two main purposes. Firstly it lists directly the major works in electronics literature: the authoritative text books, the survey articles, the main conventions and conferences, and a wealth of papers in which have been presented significant advances in the science, together with numerous valuable tutorial papers. Secondly, the aim has been to provide a means by which any paper in the now vast literature of electronics may be located. To this end, in each of 67 sections of the book (the first section covers information media) there is listed the appropriate specialized bibliographies—in other words a bibliography of bibliographies which is thought to be a unique compilation.

The compilers of the Guide obviously took upon themselves a mammoth task and there is little doubt that there will be many criticisms levelled at them for leaving certain items out and certain items in. We will be content with pointing out the omission of the British Instruments Directory and Buyers' Guide from the "Buyers' Guide" section and would suggest that, in the same section, "Radio Components" is rather an unfortunate description of the very wide range of "Electronic Components" detailed in the Exhibition Catalogue of the Radio and Electronic Component Manufacturers' Association. Surely the latter description would be more correct.

In any event, the Guide should be of great value to a great number of people although its price will probably limit its sale mainly to technical libraries.

Capacitors, Inductors and Resistors at Radio Frequencies (Notes on Applied Science No. 22)

iv + 24 pp. Her Majesty's Stationery Office, for the National Physical Laboratory (Department of Scientific and Industrial Research.)
Price 1s. 9d.

THIS SERIES of "Notes", of which this is No. 22, is published by the National Physical Laboratory with the object of providing for industrialists and technicians information on various scientific and technical subjects which is not readily available elsewhere. These "notes" are intended to fill the gaps left over from the "Notes on Applied Science No. 19" which dealt with signal generators, attenuators, voltmeters and ammeters at radio frequencies. They are concerned mainly with techniques which have been developed and used at the National Physical Laboratory in the radio frequency field over the past two decades.

While most of the sections deal with the properties of capacitors, inductors and resistors some are devoted to the determination of other quantities by measurement of capacitance, inductance and resistance and, on occasion, frequency. For this reason the measurement of the characteristics of radio frequency cables has found a place under the present heading. Its inclusion can, however, be further justified by the fact that cables constitute a distributed system of all three parameters—capacitance, resistance and inductance.

Transistors and Active Circuits

By J. G. Lonville and J. F. Gibbons
515 pp. McGraw-Hill. Price £5 12s. 6d.

THIS BOOK has been written principally for the electrical engineer and so, quite rightly, does not dwell upon the physical theory underlying the operation of transistors. Instead, it is shown how lumped parameter models can be used to represent diodes and transistors. At first sight this is an unusual approach but it is to be remembered that this is the normal practice when one is considering hard-valve theory and circuits.

Since the processes of carrier diffusion and recombination, involved in the action of semiconductor devices, do not have direct counterparts in thermionic devices, three new symbols are introduced to represent diffusion, combination and storage of particles. Models are then derived for the diode and diffusion transistor. To describe drift transistors an additional symbol is used for the drift of carriers in the base region. After surveying the various models developed, the first part of the book ends by examining other semiconducting devices and such physical processes as avalanche action, trapping and the Hall effect.

The second part of this book deals with two-port network theory and starts with an analysis of two-port linear models. Terminations are examined in detail with respect to optimizing power gain and considerable use is made of impedance charts.

An interesting introduction to the stability of linear systems is given in Chapter 12 and the effect upon performance of variations in circuit parameters follows. Passive terminations and coupling networks are next considered and the second part ends with a brief study of non-linear systems which are treated in piecewise linear fashion.

The third part is devoted to transistor amplifiers and deals with such subjects as contaminating signals, intermediate and video frequency amplifiers and feedback amplifiers. In the last two chapters transistors are first examined as simple switching elements and then in regenerative switching applications.

By combining the theory of transistors with network theory this book forms an important contribution to the subject of active circuits. F. M. Russell

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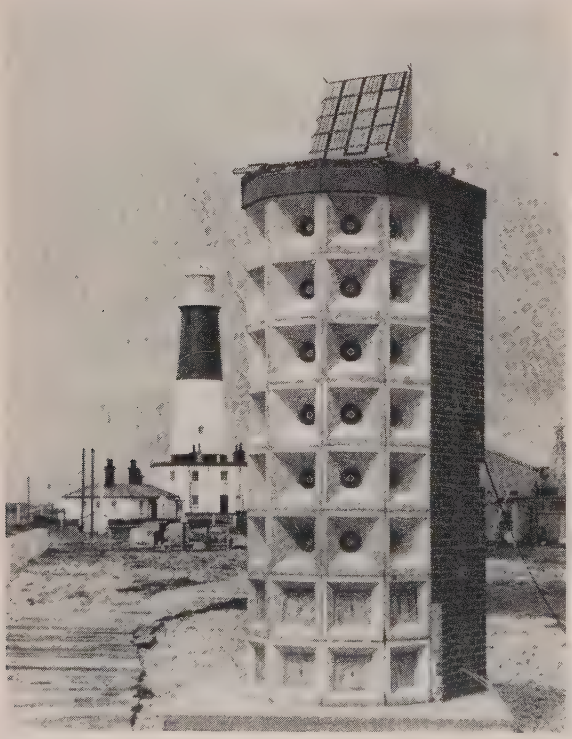
SOLAR CELL INSTALLATIONS

Continued from page 776

built takes the form of a spherical glass bulkhead-type fitting in which a block of four Ferranti MS 11E silicon solar cells, wired in series, are mounted at an angle of inclination of latitude +15°. This ensures that a maximum charge is given to the 1·2 V N.I.F.E. storage cell throughout the year. In peak sunlight conditions the maximum daily charge is of the order of 250 mA-hours. Each cell provides about 0·4 of a volt on load.

A large experimental installation containing 400 solar cells, wired in series parallel has been made, the power derived from this bank being used to charge ten N.I.F.E. storage cells. This is intended for use on navigational lights situated in river estuaries, and it is hoped that investigations carried out on this installation will reveal whether it can be used successfully as the main source of power for operating a light without having to rely on a shore-based electrical installation.

A practical application of the solar cell as a power source. The installation contains 400 solar cells, Ferranti Type MS1.



The next stage will be the construction of a model buoy which will be tested in a static water tank to determine the physical configuration of solar cells mounted thereon, when the buoy is subjected to the effects of wind and heavy seas. Buoy motion tends to reduce the power generated as the solar cells would not always be in the optimum position for maximum power output. In consequence, investigations should ultimately lead to the most suitable arrangement of solar cells to ensure that even if some of the cells were shielded from the light because of the motion of the buoy, there would always be a surface generating sufficient power to charge the cell.

The N.I.F.E. storage cell which will be mounted in the well of the completed buoy, will be of the nickel-iron, alkaline type, with a capacity of 45 A-hours. It will not only provide the power to operate either a low-wattage electric filament lamp or Xenon flash tube during the hours of darkness, but will also operate a transistor coder to give the light the desired character for identification purposes. At daybreak, a silicon light-sensitive cell will switch off the coder and the light. When darkness falls some means must be introduced to prevent the battery then discharging back through the solar cells. This is usually achieved by using a backing-off diode in each of the parallel arms of the cells.

There are still a large number of major problems to be overcome before the first fully-equipped marine buoy installation becomes a reality. These include the effects of buoy motion, prolonged periods of little or no sunlight—although the solar cell does not require direct sunlight for its operation—and the more practical problem of preventing sea birds from fouling the surface of the solar cells, thereby reducing their efficiency.

With the knowledge already accumulated by Trinity House these problems can be solved and research work at present being undertaken should ultimately lead, not only to solar-powered navigation lights, but also other solar powered aids to navigation.

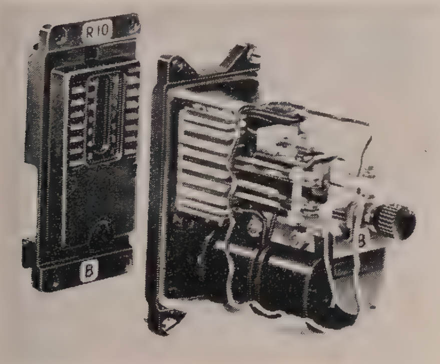
NEW COMPONENTS

Fleeting Contact Relay

Clifford & Snell Ltd. has developed a completely new method (Prov. Pat.) of producing a momentary operation of one of the contacts on a relay, either when it is energized or when it is released.

As will be seen from the illustration, a small subsidiary relay is mounted inside one of their D.2600 series plug-in relays, and this relay can be so connected that it operates for about a tenth of a second, either when the main relay is energized or when it is released, or both when it is energized and released.

Hitherto, relays fitted with a mercury switch of a type often called the "quick-strike" have normally been used, but this new relay has many advantages. For instance, it can be used in any position and in mobile applications such as on board ship, and the contact does not have to be normally open; it can be closed instead. This latter feature can be very useful as it means that the relay can be used to break the "hold" circuit of a relay or contactor, i.e. perform the same function as the "stop" push on a contactor.



Fleeting contact relay.

The principal application of this relay, the Type D.2600/F, is in fault alarm circuits, when a fleeting contact has to cause an audible alarm to sound until manually cancelled, but it also has many applications in automatic control circuits, such as bringing up and releasing contactors and starting timers.

The illustration also shows two new features which are now standard on all new D.2600 type relays. These are the use of "Mycalex" contact insulation, and a new type of base and socket which has external fixing screws, space for marking both the relay type number and the position number, and which has the numbers of the socket pins moulded on to both the back and front to facilitate the use of these sockets as test points when the relays are unplugged.

REC 101 *for further details.*

New Tubes from Dumont

Aveley Electric Ltd. have introduced into the United Kingdom a number of tubes newly developed by the Allen B. DuMont Laboratories for whom they are the agents. Amongst these is the new scan converter Type K.2070. This is a double ended, electrical input–electrical output, non-destructive readout storage tube capable of resolution in excess of 1,000 lines at 50% modulation.

Primary current modulation is employed in non-equilibrium writing. Either simultaneously or sequential reading and writing may be employed. Stored information can be retained for hours, erased in a second, or made to decay at a controlled rate while new information is superimposed.

The converter can be utilized for converting from one scan frequency or scan mode to another as in wide-to-narrow bandwidth transmission, and for data transmission and storage with random, simultaneous, and repetitive access. Half-tone operation enables transmission of video, multi-level, and time dimension information, and integrating characteristics enable build-up of repetitive signals submerged in noise and identification of superimposed information.

The K.2070 employs two high-resolution opposed-on-axis electron guns for the writing and reading operations. Both employ electrostatic focus and magnetic deflection with provision for using magnetic focus with dynamic electrostatic focus.

The maximum accelerator and focusing electrode voltages for both the write and read gun is 4,000 V d.c. The overall length of the K.2070 is approximately 23½ in., and 3 inches being the greatest bulb diameter. It will operate in any mounting position.

REC 102 *for further details.*

Scan converter Type K.2070.

Projection Tubes

The English Electric Valve Co. Ltd. has introduced four new projection tubes for use in monochrome and colour television and other applications where high brightness displays of large area may be required. The four tubes differ only in their screen properties and have the basic designation T929, with suffixes R, G, B, or W denoting the fluorescent colour of the screen as red, green, blue or white respectively.

Designed for use with Schmidt optical systems, T929 tubes give a projected picture size up to 9 ft by 12 ft from an image covering the useful tube screen area of 72 mm by 96 mm. A precision, optically ground face plate ensures a high degree of focus uniformity at the large lens apertures necessary for these applications, and the highlight brightness on a typical T929W is of the order of 6,500 millicandela per cm².

Projection tube Type T929.

A brief summary of the T929 characteristics is given below; more detailed information is available on request.

Abridged Data

Heater Voltage: 6·3 V; Anode Voltage (Typical): 50 kV; Peak Anode Current (Typical): 4·5 mA; Average Anode Current (Maximum): 500 μA; Grid Voltage for Cut Off (Typical): −120 to −190 V; Focusing: Magnetic; Deflection: Magnetic; Base: B12 A; Overall Length (Maximum): 384 mm; Diameter (Maximum, excluding anode horn): 135·5 mm; Forced air cooling of the screen is required.

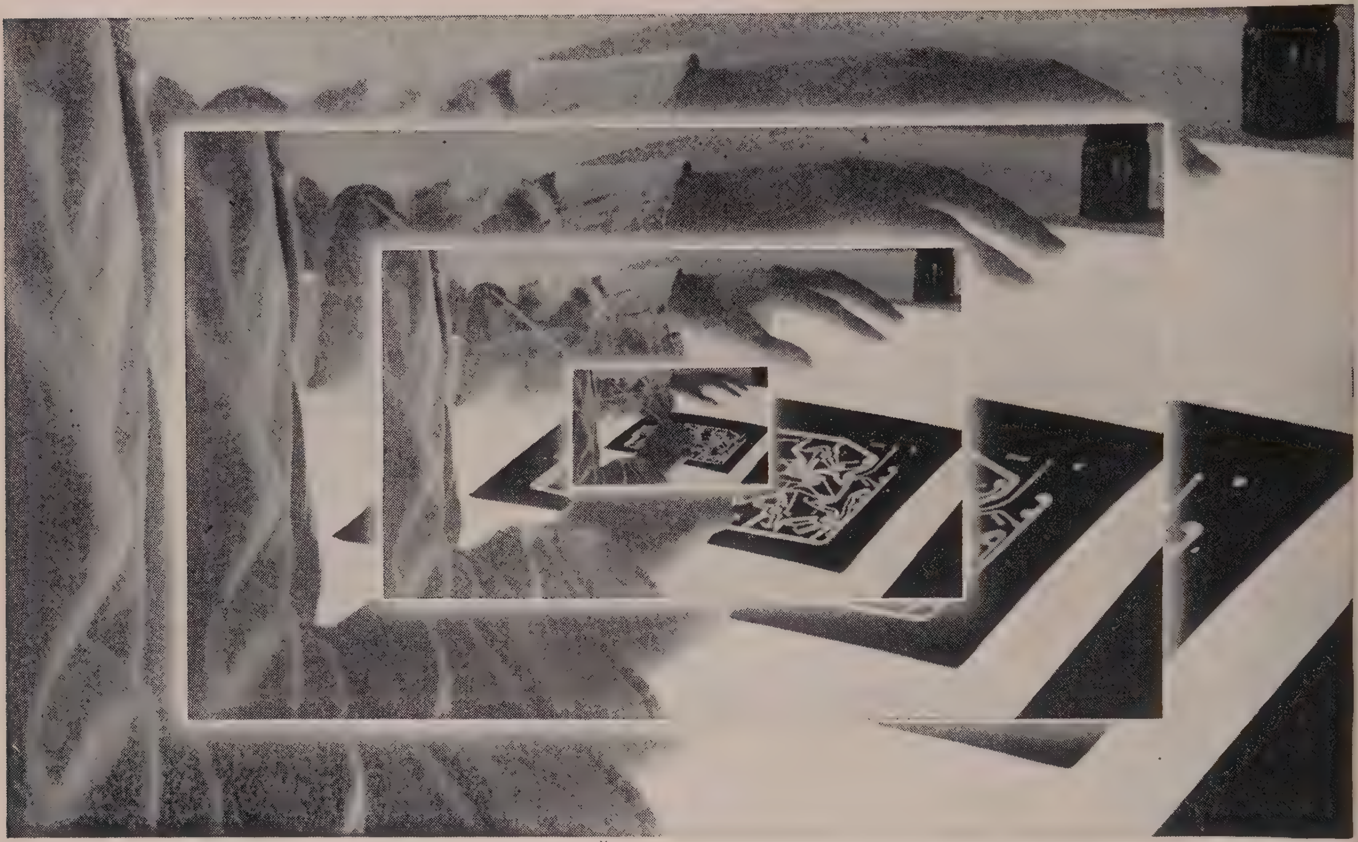
REC 103 *for further details.*

Welding Machines for Television Components

Electro Mechan-Heat Ltd. has made two special purpose welding machines for the Ferguson Radio Corporation, which will use them at its Enfield works for the high-speed production of the chassis and the

REC **32** for further information

for better printed circuits and quicker prototypes



BRIBOND ADD THREE NEW SERVICES

Now as a major step towards a new planned expansion, Bribond Printed Circuits Ltd. have appointed a new management team and reorganised their business in a new factory at Chichester. A new automatic plant has been installed which revolutionises the manufacture of printed circuits in quality but particularly in terms of firm delivery dates. Extended facilities are available for high quality sub-assembly work on printed boards as well as encapsulation and coil winding.

Why not consult Bribond about your next circuit design at the planning stage? Bribond manufacture all forms of the printed circuit: gold, silver or rhodium plating, double-sided circuits, flexible circuits, flush circuits, and resistance circuits. Component notation, and all forms of subsequent machining operations can be undertaken.

B P C BRIBOND **printed circuits**

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turret tuner spindle assemblies of television tuner units.

The machines, designed to produce one completed component every four seconds, are semi-automatic in operation. Welding cycles are controlled by electronic units embodying interlock devices, ignitron contactors and three-stage timers with printed circuits. Welding current is obtained from standard E.M.H. 45 kVA packaged welding transformers, connected to welding guns by flexible cables.

The chassis welder is provided with a pneumatically-operated work table, which is withdrawn from the welding position when at rest for easy loading. The pressing of two "start" buttons energizes a relay, which interlocks two push-buttons to start the timer. The work table then moves forward to the welding position, where it trips a limit switch admitting air to the cylinders which operate the clamps.

Air pressure continues to build up in the clamp cylinders until it closes a pressure switch connected with an electrically-operated air valve. The opening of this valve admits air to cylinders which bring the four welding guns into position.

When the electrode tips make contact with the work, air pressure continues to build up in the gun cylinders until another pressure switch is closed to initiate the "weld" stage of the timer by firing the ignitrons in the primary circuit of the transformer and so causing the welding current to flow.

The weld stage is followed automatically by a "forge" period, whereafter the clamps are released, the welding guns retract and the work table returns to the load position. In doing so it operates mechanisms which re-set the welding control circuits and also a further pneumatic device whereby the welded component is partially lifted from the welding jig to facilitate its removal.

The welding of the turret tuner assembly, which consists of two discs on a spindle, presented certain problems in the exact spacing and positioning of the discs.

A tolerance of only ±0·0015 in. was acceptable in the location of one of these discs relative to a groove in the spindle. The spacing between the two discs had to be accurate to within ±0·003 in. and certain holes in the two discs had to be aligned to within an angular tolerance of ±0° 15′ of arc.

To ensure accurate location of the first disc, the spindle is held by a jig, which incorporates electro-magnets. The disc is then slid on to the spindle and the magnets energized so that the disc is drawn to an exact distance from the end of the spindle.

The second disc is held by another electro-magnet attached to the piston shaft of a small air cylinder. By this means it can be moved pneumatically to a predetermined position on the spindle relative to the first disc. Locating pins on the ends of both electro-magnets engage with depressions in the two discs to ensure their accurate angular positioning about the shaft.

The electro-magnets are operated by a foot switch, which allows the operator to engage the locating pins with the depressions in the discs before energizing the magnets. Once the "start" buttons have been pressed the magnets remain energized until completion of the full cycle of operations.

The first stage of this cycle is the moving of the second disc to its correct position along the spindle. Back pressure in the air cylinder which controls this movement is then used to actuate a pressure switch, whereby the welding gun solenoid is energized. Pneumatically-operated welding heads now move into position and back pressure in their air cylinders is used to close a second pressure switch and initiate the weld stage of the timer.

On completion of the welding cycle, the welding heads retract, the magnets are de-energised and the moveable magnet returns to the load position. The welded component is then removed and fitted into a sizing jig, which consists of a forming block with two slightly conical faces against which the discs are pressed by impact cylinders until they conform exactly to the end faces of the block.

REC 104 *for further details.*

Hand Embossing Tool

Hellermann Ltd. has introduced the Dymo hand embossing tool in kit form, which will enable labels to be produced either horizontally or vertically.

The Dymo tool, which embosses labels on a wide range of metallic and coloured p.v.c. tapes, either adhesive or non-adhesive, can now be supplied with two separate dies that can be easily interchanged.

The introduction of vertically embossed labels will extend still further the wide range of applications for Dymo labelling in commerce and industry.

REC 105 *for further details.*

Vacuum Variable Capacitors

Four of the vacuum variable capacitors manufactured by the English Electric Valve Co. Ltd. are now available with alternative peak r.f. voltage ratings and increased maximum r.f. currents. The U30/15, U50/15 and U80/15 will in future be supplied either for 15 or 20 kV peak r.f. voltage operation and the U200/10 for either 10 or 15 kV. The maximum r.f. current is increased to 20 A for the U30/15, 30 A for the U50/15 and 40 A for both the U80/15 and U200/10 capacitors. The mechanical characteristics including outline dimensions remain the same.

REC 106 *for further details.*

"Solid-state" Circuit Elements

Following the success of the transistorized Modulator SM10, the Telephone Manufacturing Co. Ltd. now offers three more "solid-state" circuit elements—amplifier SA10, oscillator SO11 and demodulator SD10—to the same dimensions as the SM10 ($1\frac{15}{16} \times 1\frac{1}{2}$ in. diam.) and with the same high performance.

Together, it is claimed, the new elements can form the pre-assembled stages of a complete d.c. amplifier but they also have important applications when used separately in a wide variety of low-voltage circuits in commercial, scientific and military equipment.

Each of these small but robust components is encapsulated which renders them virtually proof against vibration and rough handling, and all units fit standard B9A sockets.

Amplifier SA10, with a nominal gain of 150 (which can be increased by cascading) is a general-purpose single-stage amplifier for use in d.c. amplifier circuits of the type found in servo systems, computers, etc.

Oscillator SO11, identical in appearance and dimensions to the other units, provides a reliable driving voltage for modulator SM10 and demodulator SD10. The oscillator frequency is dependent on input voltage, the maximum frequency being slightly more than 800 c/s.

The new demodulator SD10 is designed for use as a post-amplification complement to modulator SM10—or any other chopping element—and may be used as a shunt clamp or series gate. With a switching capacity of ±60 V at 2 mA peak, the SD11 can switch frequencies within the range d.c. to 1,000 c/s.

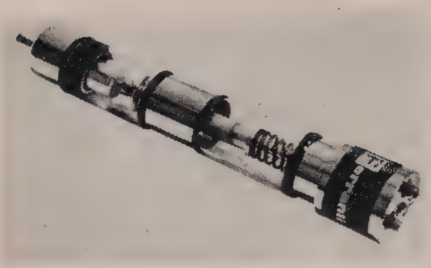
REC 107 *for further details.*

Vacuum Switch

A new vacuum switch designed primarily for high-voltage pulse-forming network switching in radar modulators is announced by Ferranti Ltd. This switch has been developed to meet a requirement for a component which would enable pulse lengths in airborne radar equipment to be changed easily.

The Type 13VSB1 switch comprises a glass and metal vacuum envelope containing two contacts—one fixed and the other moveable—both of which are insulated from the earthy end to withstand a maximum pulse voltage of 15 kV. The moving contact is actuated by means of a solenoid against a spring load, which holds the contacts closed. The switch is normally closed and the contacts only move about 0·020 in.

Ratings for this "on-off" switch are:



Vacuum switch

maximum pulse voltage 15 kV; maximum pulse current 100 A; d.c. test voltage 30 kV; operating time 5 ms maximum; contact resistance (closed position) 0·02 Ω maximum; capacity between contacts (open position) 1·5 pF maximum. Solenoid ratings are: 24 V d.c. supply; coil resistance 20 Ω ±10%; pull-in current 1 A maximum; hold-in current 100 mA maximum. These ratings apply in ambient pressures down to 560 mm of mercury, and the switch is capable of withstanding the normal shock, vibration and centrifugal tests associated with unpressurized airborne electronic equipment. The switch is designed to operate in the absence of current or voltage, and the vacuum dielectric ensures that accidental switching up to the full ratings will not result in permanent damage.

The switch is 6 in. long overall, with a diameter of 1 in. and weighs 6 oz.

REC 108 *for further details.*

Audio Triode-pentode

A recently introduced addition to the Mullard "World Series of Audio Valves" is the ECL86 triode-pentode.

Unlike its predecessor, the ECL82, the new valve has been developed exclusively for a.f. applications and offers higher sensitivity consistent with high output, making practicable the use of a greater degree of negative feedback. A signal voltage of 50 mV at the triode grid will produce 3 W of audio output at the pentode anode in a typical single-valve amplifier.

The triode section of the ECL86 has an amplification factor of 100, and a mutual conductance of 1·6 mA/V. The anode dissipation of the pentode section is 9 W, and its mutual conductance 10 mA/V (Ia=36 mA).

Special care has been taken in the design of the valve to keep the hum and microphony to a minimum. Maximum hum level referred to the triode grid is 4 μV. No special precautions against microphony are required in equipment where the input voltage is not less than 5 mV for an output of 50 mW.

The ECL86 is particularly suitable for use in stereo amplifiers. A medium sensitivity stereo pick-up gives an output of 70 mV, which is substantially more than the valve requires to give full output. Using two of the new valves, Mullard engineers have designed a stereo amplifier that gives a power output of 3 W per channel with a total harmonic distortion of 3%. A new 10 W stereo amplifier has also been designed which uses two ECL86's and one EF86 per channel, the performance of which compares favourably with the Mullard "5–10" circuit.

The ECL86 has maximum diameter of 22·2 mm and a maximum seated height of 71·5 mm. The base is B9A.

REC 109 *for further details.*

Thermostatically Controlled Oven

This oven incorporates a mercury contact thermometer which ensures a temperature stability of approximately 12°C for an ambient excursion of 90°C (−20°C to +70°C). This corresponds to an "improvement factor" of more than 300, and the temperature differential is less than 0·1°C.

The peak power consumption is 18 W, and the normal running consumption is between 4 and 10 W.

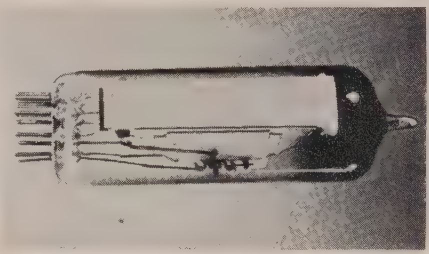
The oven is robust, and has an internal volume of $3\frac{1}{2} \times 1\frac{1}{2}$ in., which can accommodate one octal or two B7G based crystal units. It can be supplied to control at any temperature in the range 35°–90°C, for ambients up to 10°C below operating temperature.

REC 110 *for further details.*

Voltage Level Indicator

The EM87 is a new Mullard voltage-indicator tube primarily intended for use as a recording level indicator in tape recorders.

In many recorders the a.f. voltage appearing at the anode of the recording output stage is about 10 V, which is insufficient to close the display of currently available level indicators. The EM87 has a grid base of only 10 V and in addition it has a high sensitivity in the initial region of the control characteristic (Vg=OV). Over-modulation of the tape is immediately apparent, since a.f. signals greater than 10 V in amplitude cause the luminous areas to overlap, giving a brighter centre portion to the display.



Voltage level indicator tube.

The maximum ratings are: anode voltage 300 V, anode dissipation 600 mW, cathode current 5 mA, and deflection electrode voltage 300 V. The heater draws a current of 300 mA at 6·3 V.

The EM87 has the same overall physical dimensions (72·8 mm overall length × 22·2 mm diam.) and the same pin connections as the EM84. The fluorescent strip is 32·6 mm in length by 4 mm in width.

REC 111 *for further details.*

Beryllia-free Mallory 73 Beryllium Copper

Johnson Matthey & Co. Ltd. are now supplying all Mallory 73 beryllium copper strip up to 0·025 in. thick with beryllia-free surfaces. This will reduce tool wear without affecting the mechanical properties of the alloy.

Undue tool wear is attributable to the presence of beryllia, a hard and abrasive oxide of beryllium that is formed during the solution heat treatment of the alloy. The oxide is colourless and is not removed by normal cleaning or pickling methods, so that it is often present on material that appears to have a good surface finish.

A new process developed by Johnson Matthey completely removes beryllia, and the improved material is supplied at no extra cost.

REC 112 *for further details.*

Yellow Polyester Thermosetting Tape

An opaque polyester thermosetting self-adhesive tape has been introduced by Paynes Jiffytape Ltd. because many applications require a high-temperature tape of distinctive colour, which also acts as a reliable means of identification.

Like the transparent polyester thermosetting tape, the yellow has excellent solvent resistance and is free from staining tendencies. After curing, the tape will operate in temperatures up to 180°C and has a breakdown of 5,000 V.

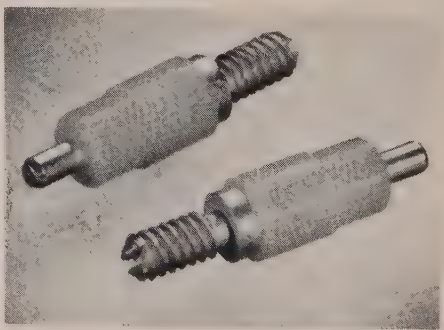
A high degree of solvent resistance is obtained by curing at 150°C for one hour and 120°C for two hours. Maximum solvent resistance is achieved by curing for double these periods.

REC 113 *for further details.*

New Sealectro Components

The following new components have been announced by the Sealectro Corporation:

1. *Threaded p.t.f.e. terminal with screwdriver slot.* This is a threaded terminal permitting high torque installation techniques combined with the standard chassis mounting employed with Sealectro "Press-fit" p.t.f.e. terminals. Designated Type FT-500TI, the terminal has a screwdriver

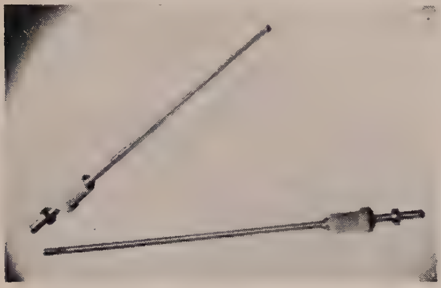


slot milled across the threaded stud to facilitate holding the mounted terminal while high torque may be applied to the terminal nut.

The overall length is 0·743 in. and a metal shoulder provides the stop when tightening the nut, at the same time maintaining a high dielectric strength path from the chassis. The mounting bushing diameter is 0·171 in.; the stud is made of silver or gold-plated brass; the p.t.f.e. body is available in any standard colour; the below-chassis stud is 0·070 in. diam.

REC 114 *for further details.*

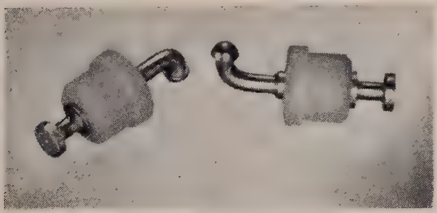
2. *"Long-reach" microminiature feedthrough.* This microminiature feedthrough has been designed with a stud similar in appearance to that of a sewing machine needle. The type number is FT-MM-47-TUR and it permits an overall "reach" of 1·500 in.—it is insulated from the chassis by a p.t.f.e. body.



The stud above the chassis incorporates a turret design and a spherical end, permitting soldering of associated circuitry, or it may be used as an 0·032 in. diam. probe 0·100 in. long. The plain stud below the chassis is only 0·025 to 0·030 in. diam.

REC 115 *for further details.*

3. *Reverse feedthrough terminal.* The Type RFT-SM-18 TUR-L2 subminiature reverse feedthrough features the standard p.t.f.e. body design and provides a 90° turn in the conductivity path. This makes the component suitable for installations requiring a feed through the chassis, and as a termination for alligator test clips placed in a vertical position from the chassis, or again, where wiring configurations are such that the 90° turn permits a straight, or axial, run from the terminal.



The overall height of the terminal is 0·378 in.; the body diameter is 0·148 in.; the metal stud terminated in turrets at both ends and made of brass, measures 0·040 in. in diam. and may be finished in solder or gold-plated.

REC 116 *for further details.*

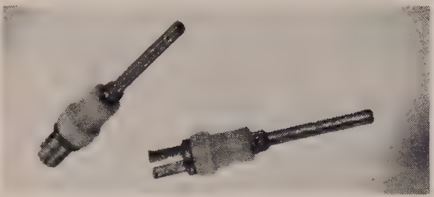
4. *High mechanical shock resistance for miniature feedthrough terminal.* The new feedthrough Type FT-DM75L2 is another Sealectro "press-fit" design whereby mounting is accomplished by press-fitting the p.t.f.e. body into a properly prepared hole in the mounting surface. Installation is simple, fast, and sure.

The overall height of the feedthrough is 0·434 in., mounting bushing diam. is 0·150 in. and overall diam. of the p.t.f.e. body is 0·172 in. The stud is of the hole-through type with a turret, permitting wiring to be run through and wrap-soldered. The hole-through is 0·031 in. diam., and the outside diam of the stud is 0·047 in.

REC 117 *for further details.*

5. *"Press-fit" terminal for encapsulated components.* The FT-MM-3SL is a microminiature type "press-fit" terminal, measuring 0·093 in. maximum diam. Mounting body is 0·075 in. diam., overall length is 0·510 in. The external stud is of the usual slotted design, and the internal stud is 0·030 in. diam. The stud is made of brass, with a solder finish.

The new "press-fit" feedthrough type provides all the inherent advantages of "press-fit" installation and p.t.f.e. insulation while simultaneously providing a positive encapsulation seal to the potting compound. This unusual combination is achieved by means of a fluted section on the metal stud immediately below the p.t.f.e. body.



REC 118 *for further details.*

6. *Magnetostrictive delay line.* The new magnetostrictive delay line permits a continuously variable output delay of from 2 μs to 20μs, and is ideally suited to laboratory work as well as a component for systems in which delay time must be adjusted to the initial "trimming" of the system. Designated Deltime Type 157 it offers the inherent characteristics of magnetostrictive delay lines including high resolution, stability and high resistance to ambient physical environments. It is compact, measuring 7 × $\frac{5}{8}$ × $\frac{23}{32}$ in., and is housed in a hermetically-sealed steel case.

REC 119 *for further details.*

MANUFACTURERS' PUBLICATIONS

Resistors

Alma Components Ltd. have recently issued pamphlets describing their precision wire-wound resistors Types L, A4, C and E, together with a selection chart which simplifies the time consuming the difficult task of selecting the resistor best suited to a given application.

REC 120 *for further details.*

Flame Failure and Burner Control Units

The FS Data Sheet, Issue 3, from Elcontrol Ltd., describes the improved FSM range of industrial flame failure and burner control units.

REC 121 *for further details.*

Racal Review

Recently published is issue No. 1 of *Racal Review*, the new house journal of Racal Engineering and Racal Instruments. This magazine is to be issued quarterly and will contain information concerning Racal equipment in use in many parts of the world.

REC 122 *for further details.*

JFD Trimmer Capacitor Catalogue

A 24-page catalogue C-61 has been announced by the JFD Electronics Corporation, which covers their range of variable trimmer piston capacitors. A special feature of the catalogue is a chart describing and illustrating standard modifications that are optional with any of their trimmers, and a list of all distributors where JFD components are in stock.

REC 123 *for further details.*

Microwave Tube Catalogue

A 70-page microwave tube catalogue is now available from Raytheon Company's Microwave & Power Tube Division. The catalogue lists 201 active, unclassified microwave tubes of all types, as well as ferrite devices, magnetic components, high-power test modulators and infra-red detectors.

It is fully illustrated with detailed descriptive specifications on each listing, and the catalogue is colour-tabbed for each section.

REC 124 *for further details.*

Cobalt-platinum Permanent Magnet Alloy

Johnson, Matthey & Co. Ltd. have issued a new data sheet describing their cobalt-platinum permanent-magnet alloy Platinex

II. This publication gives information on the heat treatment process, on reversible permeability, and on behaviour at elevated temperatures.

REC 125 *for further details.*

'Hidutac' Switches

Full details of the range of 'Hidutac' switches are given in leaflet X.5463 supplied by the General Electric Co. Ltd. The main features of these switches are unlimited full-load switching—they will break eight times their rated current; and high fault current duty. Additionally, they are compact in overall dimensions but offer ample wiring space.

REC 126 *for further details.*

Precious Metal Plating

As reliable low voltage connections for electronic equipment applications demand an extremely high standard of precious metal plating, the Automatic Telephone & Electric Co. Ltd., have developed carefully selected and controlled precious metal finishes. The service they can offer is briefly described in their leaflet on the subject.

REC 127 *for further details.*

Type 51 Relay

The Electromechanical Division of Ericsson Telephones Ltd., has recently issued a data sheet giving full technical details of their Type 51 Relay. This has been introduced to supplement the G.P. Type and is for applications where the limitations of 12 springs imposed by the miniature design restricts its wider use.

REC 128 *for further details.*

Magnadur Permanent Magnets

Mullard Ltd., has recently released their latest publication entitled *Mullard Magnadur Permanent Magnets*. This booklet contains information about the various types of Magnadur magnets and their particular applications. Factors governing the length and cross-sectional area of any permanent magnet are discussed and some general rules are given for guidance of designers using Magnadur.

REC 129 *for further details.*

EMI Electronics Post

A new method of solving the congested bandwidths problem, which will become more and more serious as new television channels come into use, is described in the summer issue of EMI Electronics Post. The suggested solution is to extend the use of wired television systems to distribute colour and coin-in-the-slot television programmes.

Other interesting features explain a unique 21 in. radar tube used for air traffic control, and EMMA—the new transistorized eye movement measuring apparatus which brings electro-oculography within the reach of advertisement designers, doctors and scientists.

REC 130 *for further details.*

Murphy News

The August edition of *Murphy News* is mainly concerned with conversions of their latest television receivers to the 625-line standard. Most of the items are of interest only to commercial dealers, although there is a short write-up of a new television aerial filter for rejecting frequencies near the receiver's i.f. band. This explains that the types of interference likely to be encountered at television i.f. are diathermy, homing beacons, and forward scatter transmissions by teleprinter. The filter is enclosed in a cylindrical metal container and consists of a printed tuned circuit having good rejection below 38 Mc/s. All the dealer needs to do is to put it in series with the receiving aerial.

REC 131 *for further details.*

EMI News Letter

Six ways in which EMI equipment can help to increase profits are described in the summer issue of *EMI Electronics Industrial News Letter*. These range from an EMI-Grimston positioning table, which enables a girl operator at General Electric Company's Telephone Works at Coventry to quadruple her output, to a battery of 30 dynamic balancing machines which help Birmingham Sound Reproducers to supply a world demand for good-quality,reasonably-priced record changers and domestic tape decks.

REC 132 *for further details.*

PERSONALITIES

Mr. G. H. J. Munro

Mr. G. H. J. Munro, above, has been appointed Director and General Manager of Aircraft-Marine Products (G.B.) Ltd. Mr. Munro began his career with AMP in 1957 as Sales Manager, moving into general management early this year. He has had over 20 years' experience of specialized selling in the electrical industry. Before joining AMP, Mr. Munro was responsible for home sales at Acheson Collard, the company he rejoined after war service with the R.E.M.E.

The Company's new factory at Port Glasgow was opened by the Rt. Hon. John S. Maclay, M.P., C.M.G., Secretary of State for Scotland, on 25th September last. The new plant incorporates advanced production methods and will offer a greatly expanded service to British industry and overseas markets.

Mr. R. A. Bryce and Mr. A. F. Leith

Mr. R. A. Bryce, Joint General Manager (Sales) of The Ever Ready Co. (G.B.) Ltd., has decided to emigrate to Australia with his family, and will therefore be resigning from the Company as at the 31st December, 1961.

Mr. A. F. Leith, Manager London Sales Office, has been appointed Company Sales Manager as from 1st September, 1961.

Mr. E. W. Rae

Mr. E. W. Rae has been appointed to the Kemet Division of Union Carbide Ltd., to promote the sales of Kemet solid tantalum capacitors, which they are now marketing. United Kingdom manufacture of solid tantalum capacitors is planned to start at the Aycliffe (Co. Durham) factory in the near future.

Mr. Rae was previously with A.B. Metal Products Ltd.

Brigadier J. D. Haigh

The Plessey Co. Ltd. has appointed Brigadier J. D. Haigh, O.B.E., M.A., M.I.E.E., above, as General Divisional Manager of a group of Divisions including the Wiring and Connectors Division, the Capacitors and Resistors Division and Preformations Ltd.

Brigadier Haigh was one of Britain's early radar experts and from 1939 until 1941 was a radar instructor at the School of Anti-Aircraft Artillery. In 1946 following intelligence duties in the United Kingdom and Far East. He joined the Ministry of Supply where he was responsible for the development of army radar equipment until 1950. In 1953, on returning from Singapore where he had commanded an Air Formation

Signals Regiment, Brigadier Haigh rejoined the Ministry of Supply, being appointed Director of Electronic Research and Development in the following year.

Brigadier Haigh joined The Plessey Co. Ltd. in 1958, and since February 1960 held the position of Divisional Manager of the Capacitors and Resistors Division, Swindon.

Mr. E. J. Aaronson

Mr. E. J. Aaronson, F.C.A., was appointed General Manager, Overseas Operations of The General Electric Company Ltd., on 1st July, 1961. He was previously Economic and Financial Advisor (Export).

Board of Directors—Semiconductors Ltd.

Following the recent announcement that Semiconductors Ltd. has become a wholly owned subsidiary of The Plessey Co. Ltd., Plessey have announced the formation of a reconstituted Board of Directors as follows:

Sir Allen Clark (Chairman), Mr. John A. Clark, Dr. J. Reekie, Mr. D. H. Roberts, Mr. G. C. Gaut, Mr. G. Campbell.

Mr. A. H. Oldham

Pinnacle Electronic Products Ltd. has announced the opening of a new division within the Pinnacle organization catering exclusively to the needs of the industrial valve users.

In charge of sales and general administration will be Mr. A. H. Oldham, who has recently joined the Company, after considerable experience of this field with A.E.I.

Mr. S. S. Eriks

The Queen has appointed Mr. S. S. Eriks, Managing Director of Mullard Ltd., as an honorary Knight Commander of the Order of the British Empire in recognition of his services to British official interests.

Mr. Eriks was born in Oosterzee, Holland on 26th September, 1900 and, after leaving Rotterdam University, joined N.V. Philips', Eindhoven in 1924. Following several overseas committments for the Company, which included the implementation of radio interests in Australia and New Zealand, he was appointed General Manager of the Mullard Company, subsequently becoming Director. During the war all the Philips interests in Great Britain were integrated into the war effort under Mr. Eriks, and during this period the Mullard Company provided nearly 50% of all radio valves used by British Defence Services, and the group in Great Britain became one of the largest manufacturers of communications equipment.

After the war when, contact with Eindhoven was resumed, Mr. Eriks became Managing Director of Mullard Ltd. and also Chairman of Philips Electrical Industries Ltd., which administers N.V. Philips' interests in the United Kingdom.

Mr. Eriks was awarded the O.B.E. in 1948 and was appointed Officer in the Orde van Orange-Nassau by Queen Juliana in 1953.

Mr. J. D. Percy

Mr. J. D. Percy has been appointed Technical Sales Manager of Cossor Radar and Electronics Ltd., Harlow Essex.

In early youth Mr. Percy was associated with John Logie Baird and was one of his original band of assistants at the very commencement of television (1928). He remained with Baird until the outbreak of war in 1939.

During the war he was attached to the submarine service, serving with flotillas based in the United Kingdom, Mediterranean and Far East. During this period he specialized particularly in underwater electronics and noise suppression in operational boats.

When the war had ended, Mr. Percy was transferred to the Royal Canadian Navy, serving at Naval Headquarters in Ottawa and later with the first squadron of submarines to be based in Canada in peacetime. He joined Cossor (Canada) in Halifax, Nova Scotia, on leaving the Canadian Navy in 1955, transferring to Cossor Radar and Electronics Ltd. in 1958, where, until his new appointment, he was Controller (Administration) Technical Division.

Mr. C. R. Russell

Mr. C. R. Russell, Manager-Export Sales, M-O Valve Co. Ltd., has been appointed Product Planning Adviser to the Management of the Company. He will retain his interest in sales while discharging his new responsibilities.

His appointment involves guidance of policy with respect to new products, by the provision of all the information and statistics necessary to anticipate new markets for valves and cathode-ray tubes.

Mr. Russell joined the parent company in 1947 and, until his appointment as Manager-M-O. V. Export Sales in December 1960, he was engaged on valve research work at the Wembley Research Laboratories, now the Hirst Research Centre, of the General Electric Company.

Mr. R. A. V. Noakes

Walmore Electronics Ltd., are expanding their sales effort on special electronic valves, cathode-ray tubes and semiconductor devices. Mr. R. A. V. Noakes is joining the Company as their Area Representative for London E., E.C., and S.E. districts, Kent and Sussex.

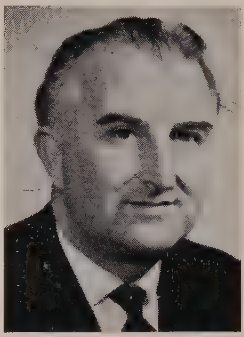
Mr. Noakes is 32 years old. For the last six years he has been on the staff of A.E.I. Ltd. (Ediswan/Mazda) where he was responsible for sales planning of valves and semiconductors.

Belling & Lee Appointments

The following management appointments have been made by Belling & Lee Ltd.:

Mr. Brian M. Lee, Director, and Manager of the Industrial Division, is now the Company's Assistant General Manager.

Mr. J. W. F. Golley, General Works Manager, is now Works Director.



Mr. J. W. F. Golley

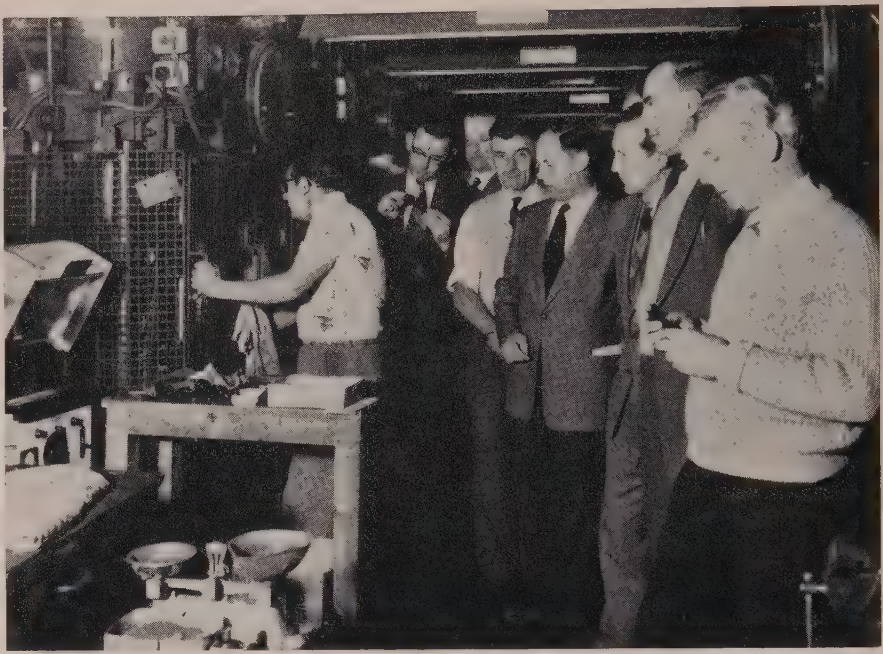
Mr. J. R. Turrill has joined the Company as Sales Manager.

Appointments at Lorlin Electronics

Mr. J. E. Noad, M.S.M.A., A.M.Inst.B.E., has joined Lorlin Electronics Co. Ltd., and will be responsible for the sales of rotary switches and capacitors now manufactured by the Company. Mr. Noad was the Sales Director of the Walter Group of Companies, and his experience in the marketing of radio switches has been continuous for over 30 years.

Mr. R. Nolan, formerly Chief Engineer and Chief Inspector of Walter Instruments Ltd., has been appointed Works Manager of the Company to supervise the production of switches, capacitors, and other components which the Company will now manufacture in their factories at Billingshurst, Sussex.

ACTIVITIES in the Industry



Members of Bletchley Centre Associate Section of the Institution of Post Office Electrical Engineers, study intricate mouldings as they are removed from one of the moulding presses at the electrical component factory of Painton & Co. Ltd., Northampton. This visit to the modern Kingsthorpe factory was the first of a series of visits to various manufacturing concerns arranged as part of the Centre's winter programme.

Tung-Sol/Chatham

Tung-Sol Electric Incorporated, New Jersey, U.S.A. has appointed Walmore Electronics Ltd., as its distributors in the United Kingdom.

A wide range of valves and semiconductor products are now available, and also included in this arrangement are valves of "Chatham" trademark—Chatham being a subsidiary of Tung-Sol.

New BICC Coventry Depot

British Insulated Callender's Cables Ltd. announce that a new Depot has been established in Coventry within the organization of BICC Midlands Region. The opening of the new depot took place on Monday, 4th September.

The new depot, which is at 37 Broad Street, Coventry, will serve the Birmingham Branch, and will still further improve customer services within BICC Midlands Region. It will hold stocks of rubber, plastic, mineral insulated, p.v.c. and armoured cables, claw-type cleats, glands, box compounds, welding cables, accessories and any special cables to meet local requirements.

'Panelec' Heating Cables

The heating of the road surface of the new Hammersmith Flyover in London will be by means of approximately 66 miles of heating cables laid in panels and provided by the Panelec Heating Division of British Insulated Callender's Cables Ltd. The Hammersmith Flyover will, it is believed, be the first flyover in the world to be completely heated.

Vacuum-forming Polypropylene Sheet

A question which has been exercising minds on both the engineering and materials sides of the plastics industry is that of exploiting the outstanding merits of polypropylene in vacuum formings. One problem is the production of a truly homogeneous sheet as a starting material; another is the familiar one of economy—the achievement of a cycle-time comparable with those for materials having greater thermal conductivity and lower softening point.

The high softening point of polypropylene is indeed one of the characteristics which gives it such marked superiority over other thermoplastics such as its near relation polythene. Telcon Plastics Ltd., of Orpington, Kent, have had great faith in polypropylene ever since it first made its appearance, and for some months have been carrying out development work with it.

Meanwhile, makers of vacuum forming machinery have been working on the design and production of equipment capable of providing a heating density sufficient for the needs of polypropylene and other plastics of high softening point. Parnall & Sons Ltd. of Bristol have been extremely active in this direction.

The two converging lines of investigation met at the International Plastics Exhibition at Olympia this year, when Parnall were able to demonstrate on their stand the production of complex formings, having a 1:1 draw ratio, from sheet $\frac{1}{8}$ in. thick, in an overall time-cycle of 1 min. 50 s. The machine used was the Parnavac 2721 H.D., the smallest of their range of sandwich heating machines with upper and lower heaters being rated at 9 kW and 3 kW respectively.

The formings, which were made from Telcon polypropylene sheet, of $\frac{1}{8}$ in. and also of $\frac{1}{16}$ in. gauge, were of exceptional uniformity, both in thickness and mechanical strength, and their surface finish was far better than any hitherto seen in polypropylene formings. It would appear that much of the difficulty in vacuum forming the material has been overcome.

The Parnall machines are available in sizes up to 72 × 48 in., and Telcon Plastics Ltd. produce sheeting, in polypropylene and other thermoplastics, including polystyrene, p.v.c., polythene and a.b.s. resins, in widths up to 54 in. and gauges ranging from 0·020 in. to $\frac{3}{8}$ in.

G.E.C. Distribution Scheme

Mr. R. H. Phillips, Managing Director of G.E.C.'s Installation Equipment Group, commenting on his group's new trading policy in a statement said, "if our share of export and home markets is to increase with the evolution of a new concept of European trade, we shall have to think again about service to our customers".

He added that there will be a direct control of the distribution of the Group's extensive range of products, as larger depots of its own were to replace the shared depots of the old G.E.C. network before the end of September.

From six large depots, in London, Glasgow, Birmingham, Leeds, Preston and Gloucester, the group will be able to step up its deliveries to customers throughout the United Kingdom. The London depot will also service export customers.

Each distribution centre will carry considerable stocks of Pirelli-General cables, G.E.C. low tension switchfusegear, contactors, fuses, conduit, trunking and a vast range of associated fittings and wiring accessories. The depots will be organized on most up-to-date lines, mechanized as far as possible, and their siting will enable a speedy service of all catalogue items to be maintained in the U.K.

Mullard Equipment Ltd.—New Factory

The commercial divisions and most of the production staff of Mullard Equipment Ltd. moved to their new factory at Crawley New Town, Sussex, on 4th September, 1961.

The new 134,000 sq. ft. plant is on a site of 17 acres on which expansions are planned to be made in the future. The new buildings are constructed so that they can conveniently form part of a larger unit.

The factory has been designed and built in conjunction with the Company's Central Plant Department, and the address is: Mullard Equipment Ltd., Manor Royal, Crawley, Sussex.

Lorlin Electronics Ltd.

Lorlin Electronics Co. Ltd., have acquired the plant, tools, assembly and test equipment used by Walter Instruments Ltd. in the manufacture of rotary, slide and lever switches, together with the existing stocks of piece parts and materials, and will continue production immediately in their factories at Billingshurst, Sussex.

All of the previous range of switches will be available, and new types will be introduced as tooling is completed.

The Plessey Co. Ltd.

The Philco Corporation of Philadelphia has sold its minority interest in Semiconductors Ltd. of Swindon, Wilts., to The Plessey Co. Ltd. By this transaction Semiconductors Ltd. becomes the wholly owned subsidiary of Plessey and continues as a non-exclusive licensee of Philco with respect to the manufacture and sale of transistors.

Hawley Products Moves to Swindon

Hawley Products Ltd. has moved from Tottenham to a new and larger factory at Swindon. The new premises will accommodate the increased production facilities necessary to meet the growing demand throughout industry for moulded fibre products.

The new address of Hawley Products Ltd. is Cheney Manor, Swindon, Wiltshire.

Ferranti Electric Incorporated

In order to centralize activities, Ferranti Electric Incorporated of New York have recently opened a new electronics factory at Plainview, Long Island, New York. Facilities previously provided at Hempstead and Brooklyn have now been transferred to this 7-acre site which is adequate to allow for future expansion.

The new factory, which covers an area of 50,000 sq. ft. and employs approximately 150 people, is engaged primarily in the manufacture of magnetostriction delay lines and small transformers. Test and demonstration facilities are also provided for other products, such as viscometers, tape readers, aircraft instruments and cathode-ray tubes, imported from the parent Company in the United Kingdom.

English Electric K347 for R.N.A.S.

English Electric Valve Co. Ltd., K347 600 kW klystrons will be supplied with the Marconi Type S264A/H radar which has been ordered for the Royal Naval Air Station, Yeovilton. The K347 is an external cavity tuned klystron operating in the 585 to 610 Mc/s frequency range. Repeated tuning operations can be made, to meet changing operational requirements, without stressing or damaging the tube.

This klystron has also been ordered for use in Marconi 50 cm commercial radar equipments in Belgium, Denmark, India, Italy, New Zealand and Great Britain.

Imhofs Export Drive

In September, Imhofs had two mobile exhibition vehicles selling for them on the continent—one in Amsterdam and one in Copenhagen. Each of these vehicles is a completely self-contained mobile exhibition. They carry a comprehensive selection of Imhofs standard range of instrument cases, raks, consoles and accessories including the Imlok construction systems. To show the versatility of Inlok, all of the interior display shelves and fittings have been made with Imlok.

Originally, Imhofs built one of these vehicles to cover both the home and export markets but the demand from their overseas agents made it clear that this vehicle was going to be permanently required on the continent. The second vehicle was therefore built to cover the home market but it is now found that there is sufficient justification in having both vehicles on the continent. Already this year, Imhofs have made extensive tours in Holland, Belgium, France, Norway, Sweden and Denmark and they will, later in the year, be covering Luxemburg, Germany, Austria, Switzerland and Italy.

To assist sales in these countries, Imhofs have a ten-language version of their catalogue.

Servomex Export Sales

Servomex Controls Ltd. have sold an assortment of 39 a.c. and d.c. voltage stabilizers to the Institute of Physics at Helsinki University and the Italian firm Sicedison, have ordered four of the latest infra-red liquid analysers.

Export sales are now rising very fast, and Servomex expect to reach £70,000 this year.

B.O.A.C. Boost for Electrical Exports

British exporters of a wide range of household electrical goods to Canada and the U.S.A. will benefit from cheaper cargo commodity rates to Montreal and New York now available on all B.O.A.C. flights from London, Manchester and Glasgow.

The new rates (subject to Government approval) which also apply to importers, range from 6s. 4d. per kilo for consignments of more than 45 kilos to 5s. 9d. per kilo for more than 100 kilos.

The rates apply to radio, television, phonograph and sound recording sets for household use, as well as a wide range of other household electrical goods including dish washing machines, drying machines, floor polishers, freezers, frying pans, grillers, hot plates, ironing machines, kettles, lamps, mixers, pressure cookers, refrigerators, vacuum cleaners, sewing machines, toasters and many more.

For consignments of 1,000 kilos and more the rate is 5s. 2d. a kilo to New York and 5s. 1d. a kilo to Montreal.

New, cheaper commodity rates are also available for British exporters of bulk electrical machinery.

Mobile Radio Communication Equipment

The General Electric Co. Ltd. of Coventry and Storno-Southern Ltd. of Camberley have announced that arrangements were recently made whereby Storno-Southern Ltd. took over responsibilities of marketing, servicing and installing G.E.C. mobile radio equipment as from the 4th September, 1961.

In order to ensure close technical liaison and continuity of current commitments, certain engineering staff were transferred from the General Electric Co. Ltd. to Storno-Southern Ltd., who have established an office with sales and servicing facilities and a spares depot at Coventry.

The General Electric Co. Ltd. are continuing to manufacture their range of communication equipment on a contract basis.

Storno-Southern Ltd. are already manufacturing a range of high quality frequency modulated equipment, and are now able to offer G.E.C. amplitude modulated equipment for existing users of a.m. systems.

Raytheon-Elsi AG

The Raytheon Company has formed a new subsidiary to market electronic components in Europe. The new firm, Raytheon-Elsi AG, will have its headquarters in Switzerland.

Raytheon-Elsi AG will promote and sell components manufactured by Ratheon and Elettronica Sicula, Palermo (Elsi). Products to be marketed by the new firm include microwave, receiving and industrial tubes; transistors, diodes and other semiconductor devices; rectifiers; and magnetic and electromechanical components.

Raytheon-Europe AG holds a 51 percent interest in the new corporation with the remaining interest owned by La Centrale Finanziaria Generale S.P.A.

Special Technical Conference for AMP (G.B.) Staff

Production executives, industry managers and area sales engineers, with head office technical staff of Aircraft-Marine Products (Great Britain) Ltd. attended a special technical conference at the Rembrandt Hotel, London on 28th August.

The Conference was specially staged to discuss new fields of development and technical advances concerned with the whole range of AMP activities. In particular, the occasion was utilized to familiarize all staff with the AMP in-cert connectors.

Principal speakers at the Conference were Dr. J. Redslob, Head of Connector Division in America and Mr. S. S. Froehlich, Sales Manager International Division, both of whom had flown over from AMP Harrisburg, Pennsylvania. Other speakers included Mr. G. H. J. Munro, Director and General Manager, and Mr. T. F. Blyth, General Sales Manager AMP (Great Britain) Ltd.

Expansion of Vactric Control Equipment Ltd.

At the time of the acquisition of the Share Capital of Vactric Control Equipment Ltd. by the News of the World Organization, mention was made that it was planned to expand the Company's facilities. Substantial premises have now been acquired by Vactric Control Equipment Ltd. in Surrey.

Top priority is to be given to the erection of a new block to house the Development and Applied Research Departments, and, as additional space becomes available, the Company will gradually concentrate all its activities into this area.

Elliott-Automation Ltd. and C. A. Parsons & Co. Ltd.

Elliott-Automation Ltd. and C. A. Parsons & Co. Ltd. have joined the British Space Development Company.

Elliott-Automation will be represented on the technical committee by W. R. Thomas, B.Sc., M.I.E.E., A.F.R.Ae.S., Joint General Manager of Elliott Brothers (London) Ltd. C. A. Parsons & Co. Ltd. will be represented by H. M. Finniston, Ph.D., B.Sc., A.R.C.S.T., F.I.M., Deputy Research Director.

There are now eleven leading British aircraft and electronic companies who are members of British Space Development Company, and the powerful technical committee are calling on the wide range of engineering knowledge possessed by the member firms.

New Service Company

Philips Electrical Industries Ltd. announce the formation of a subsidiary company—Amalgamated Electric Services Ltd., Waddon Factory Estate, Croydon, Surrey; telephone number CROydon 7722.

The new company will take over all the service activities at present carried on at Waddon by the Central Service Departments of Cossor Radio & TV Ltd., Philips Electrical Ltd. and Stella Radio & TV Ltd. In addition, it will be officially appointed service agents for Peto Scott Electrical Instruments Ltd., Weybridge, and Ajax Domestic Appliance Co. Ltd. (Ada Halifax).

The decision to form the new company has been taken with a view to streamlining and simplifying both the technical and administrative procedures to ensure increased efficiency and reduce indirect costs as much as possible.

Mobile field engineers will be maintained throughout the country primarily to service domestic appliances but also to provide full support to radio and television dealers which has been available from the Central Service Department, Waddon, for many years past.

From September all orders for spare parts, apparatus for repair, requests for technical information etc. which have previously been addressed to the service departments of Philips, Cossor or Stella and to similar service sections relating to Ada and Peto Scott should be addressed to the new company.

Midland Silicones Open New Birmingham Offices

To cope with the increased volume of work and to offer better facilities for customer service on-the-spot, Midland Silicones has moved its Birmingham Sales Office to new and larger premises at:

Midland Silicones Ltd.,
Lichfield House,
Smallbrook,
Ringway,
Birmingham 5.

The areas covered by this office are the Midlands, South Wales and the South West, and it will be staffed by the existing sales and technical representatives headed by Mr. J. J. Newlands as Manager.

These new offices will now enable Midland Silicones to maintain a continuous service, either for visitors or enquiry by telephone and further qualified staff, as part of planned expansion, can easily be accommodated.

Orders for Commercial Marine Radar

During the recent opening of their new radar training school at Lambeth Pier, Decca Radar Ltd. announced that total orders received for commercial marine radar reached 11,000 sets on the 15th July. This achievement by British industry is outstanding when viewed in the light of the fact that the world total of radar fitted merchant ships is currently estimated to be only about 22,000. In addition to supplying commercial marine radar to the merchant fleets of every maritime nation in the world, Decca Radar Ltd. also supply equipment to the fleets of some 41 countries and have recently received substantial repeat orders from the Royal Navy and other navies in this more specialized field.

The new radar training school has been transferred to Lambeth Pier from its old site at Blackfriars where it has been in operation since 1950 at Scantlin Pier. The total number of men trained by Decca Radar since training was first started is over 4,300. This includes over 2,000 masters, deck officers and radio officers. The new training school is located in completely reconstructed and redecorated buildings on Lambeth Pier which has been leased to Decca Radar by the Port of London Authority. Two lattice masts have been erected on the pier dolphins to carry the radar aerials and have a well-balanced appearance. In addition to the training facilities the pier will also be the London berth of the company's two demonstration vessels m.y. *Navigator* and m.l. *Scanner*.

British Colour Television at U.S. Medical Conference

New close-circuit colour television from Britain designed for hospital use, was among the highlights of the Fourth International Conference on Medical Electronics which opened in New York on the 17th July.

The system, designed by E.M.I. Electronics Ltd., was demonstrated for the first time to leading American surgeons by Fairbanks Morse & Co., major industrial subsidiary of Fairbanks Whitney Corporation, under a recent marketing agreement with the British Company.

The large-screen projector used showed medical men how operations can be screened to big audiences giving true-to-life colour reproduction.

The new E.M.I. colour camera is said to be more compact, less expensive and able to work under poorer lighting conditions than any available in the United States. Experts in America believe that it will help to speed medical training programmes to relieve the growing shortage of skilled doctors.

Radio Hobbies Exhibition

The 1961 International Radio Hobbies Exhibition is to be opened on 22nd November in the Old Hall of the Royal Horticultural Society in London. The Exhibition is sponsored by the Radio Society of Great Britain and exhibitors will include the Army, Navy and Royal Air Force.

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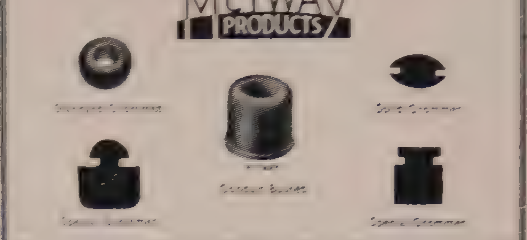

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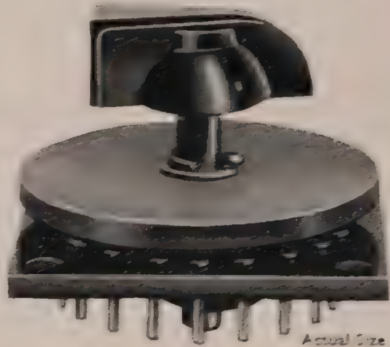

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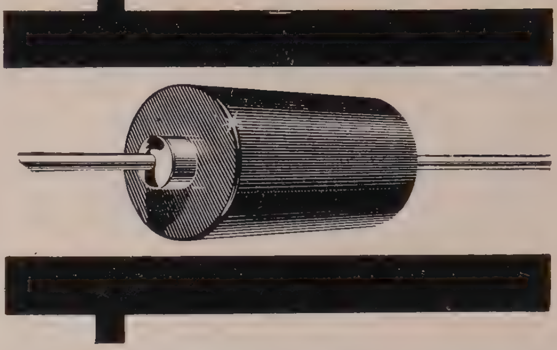

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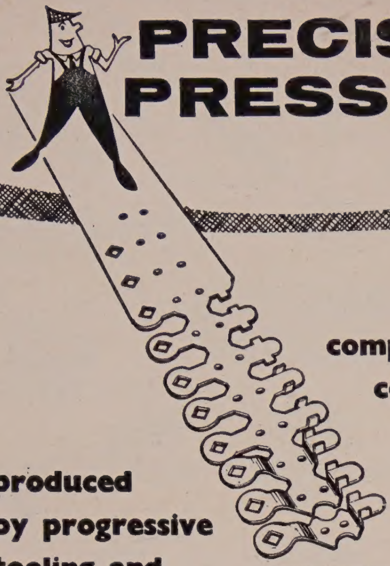

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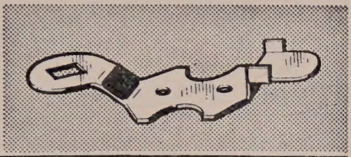

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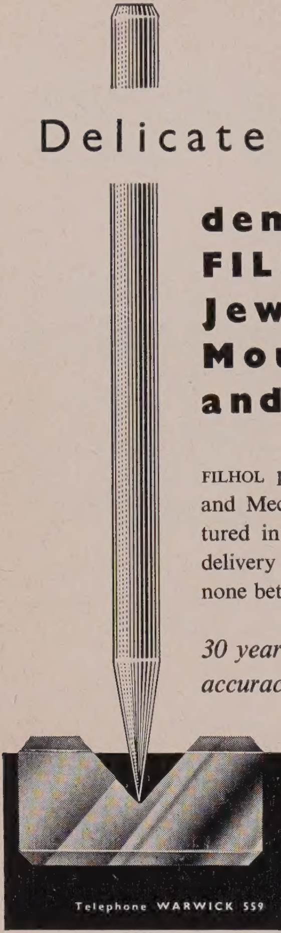

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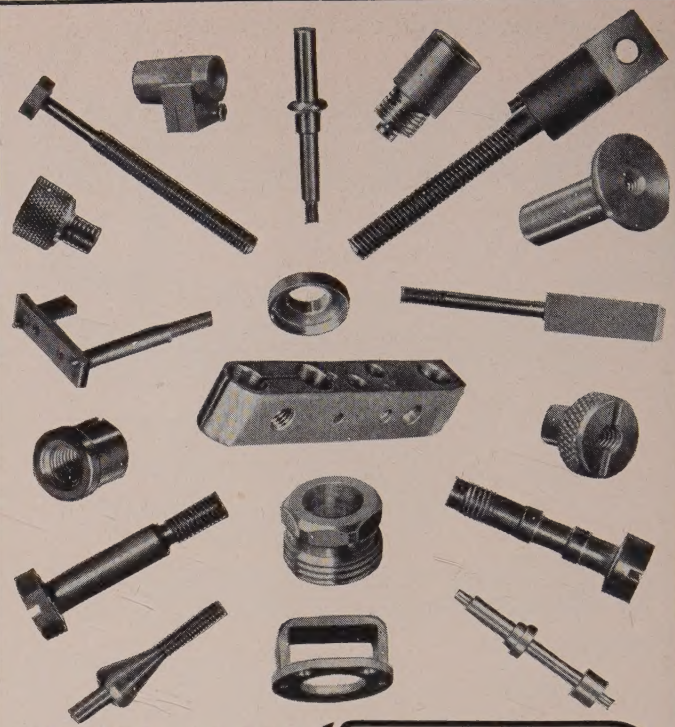

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INDEX TO ADVERTISERS

Page

Adams Bros. & Burnley Ltd. 718
Aircraft-Marine Products (GB) Ltd. September
Amphenol-Borg Ltd. 722
Ardente Acoustic Laboratories Ltd. 724
Ariel Pressings Ltd. Back Cover
Ashburton Resistance Co. Ltd. 792
Atlas Plating Works Ltd. September
Automatic Counting & Switching Equipments September

Becker Equipment & Lifts Ltd. 791
Boddington, W. H., & Co. Ltd. 718
Bound Brook Bearings Ltd. 720
Bradley, G. & E., Ltd. September
Brandauer, C., & Co. Ltd. 720
Bribond Printed Circuits Ltd. 782
Britec Ltd. September

Carr Fastener Co. Ltd. September
Classified Advertisements 795
Crawley Nameplate & Engraving Co. Ltd. 795

D.T.V. Group, The 718
Dartronic Ltd. 710
Davall Gear Co. Ltd., The 795
'Diamond H' Switches Ltd. 724
Duratube & Wire Ltd. 794

Electronic Engineering Association 712
Evans, Frederick W., Ltd. 795

Farnell Instruments Ltd. 794
Filhol, J. P., Ltd. 794
Formica Ltd. 715
Forrest Transformers Ltd. 793
Frost, N. T., Ltd. September

Goodyear Transformers Ltd. September
Grelco Ltd. September
Gresham Transformers Ltd. September

Hart, J. M., & Co. Ltd. 726
Harwin Engineers Ltd. September
Hassett & Harper Ltd. 714
Henley Burrowes & Co. Ltd. 791
Hewell Spring Co. Ltd. September
Hughes International (UK) Ltd. September

Imperial Chemical Industries Ltd. 727

Johnson, Matthey & Co. Ltd. 725

Page

K.G.M. Electronics Ltd. September

Lewis Spring Co. Ltd., The 716
Lorlin Electronics Co. Ltd. September
Lucas, Joseph, Ltd. September

Magnetic Devices Ltd. September
Mallory Batteries Ltd. 723
Mansol (GB) Ltd. 726
Marston Excelsior Ltd. 717
McMurdo Instrument Co. Ltd. September
Metway Electrical Industries Ltd. 726-791
Modern Plastics Ltd. 792

N.S.F. Ltd. September

Painton & Co. Ltd. September
Parmeko Ltd. Front Cover
Palmer, G. A. Stanley, Ltd. 716
Permacel Tapes Ltd. 728
Premier Spring Co. Ltd. September
Pressac Ltd. 719

Rejafix Ltd. 796
Reliance Mfg. Co. (Southwark) Ltd. September
Rendar Instruments Ltd. September
Ross Courtney & Co. Ltd. September
Round, B. J., & Sons Ltd. September
Rundle, A., (Upper Norwood) Ltd. 795

Salford Electrical Instruments Ltd. 714
Salter, Geo., & Co. Ltd. September
Sanders, H. G., & Son Ltd. September
Sherwood Instruments Ltd. 794
Sintered Glass to Metal Seal Co. Ltd. 721
Smallbone & Son Service Station Ltd. 796
Smith, John, Ltd. 793
Smith, S., & Sons (England) Ltd. Inside Back Cover
Standard Telephones & Cables Ltd. 711
Sufflex Ltd. 730

Telephone Mfg. Co. Ltd. 713
Tew, W. H., & Co. 793
Tucker Eyelet, Geo., Co. Ltd. Inside Front Cover

Unbrako Socket Screw Co. Ltd. September
United Trade Press Ltd. 792

Vitos Ltd. 722

Wallis Engineering Co. (Birmingham) Ltd. 793
Welconstruct Co. Ltd. 791

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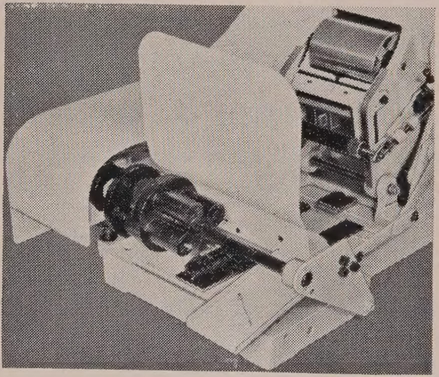

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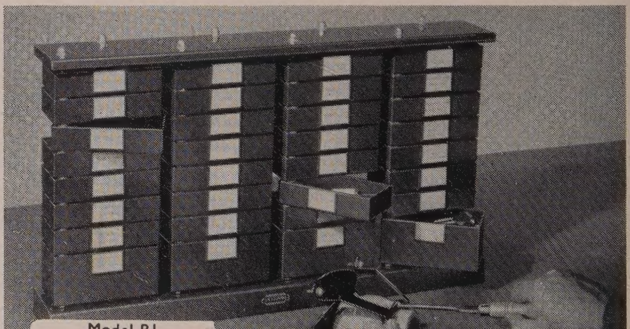

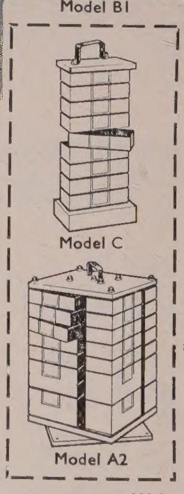

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